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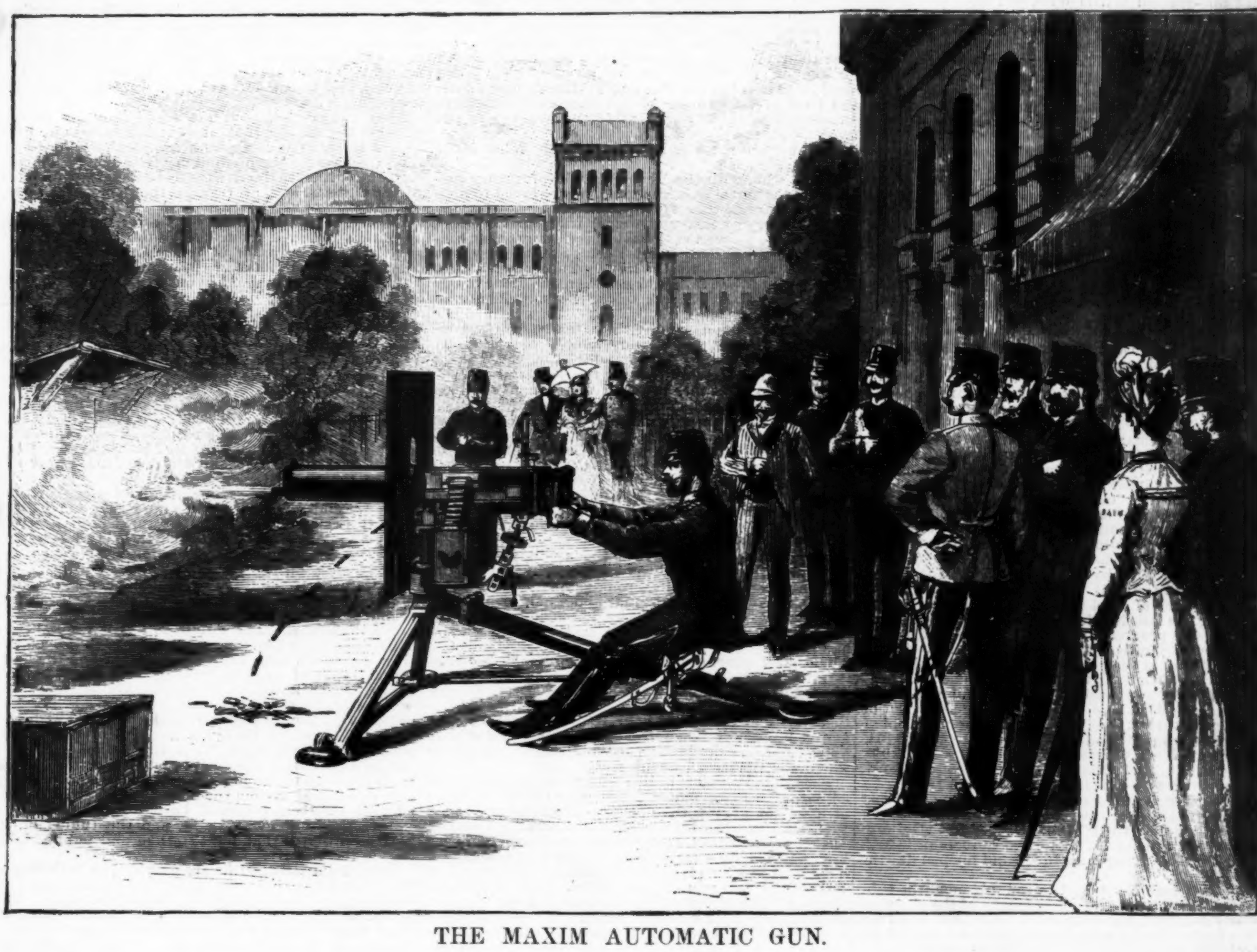
THE HIRAM MAXIM GUN.

THE Hiram Maxim rapid-firing gun with automatic repeating device is now to be introduced into the Austrian army.

The firm of Krupp, at Essen, has obtained from the inventor and the owner of the patent the exclusive right to manufacture these guns for the next twenty years. At Crayford, England, there is a large factory for manufacturing similar repeaters. Early in the seventies Major V. Plonnies, and in 1883 Major Thiel, in his work "Das Infantriegewehr," predicted that in the small fire-arms of the future the power of the powder, as it manifested itself in the recoil, would be utilized for opening the breech, throwing out the cartridge shells, cocking the trigger, etc. All of these things have been done by guns of different constructions, among which that of the American engineer Maxim was the first, and it is now, with the improvements he has made, the most practical. This construction enlarges upon the ideas of Plonnies and Thiel by the addition of reaction springs, by means of which the entire operation of firing—that is, the introduction of the cartridges, the shooting, and removal of the charge—is performed automatically as long as the weapon is in use. The *Times* recently noticed trials of guns of this kind in Italy. Seven different ones were used, from some of which single shots were discharged, while from others from fifty to one hundred shots were fired in quick succession, without stopping. By preparing and introducing new belts, each one of which carries 334 cartridges, 600 shots can be discharged from a Maxim gun of the smallest caliber per minute. A mechanism is provided for automatically regulating the intervals between the shots. After 400 shots have been fired in rapid succession, the water in the water-jacket which surrounds the barrel begins to boil and generate steam, but it can be replaced by fresh water without any interruption of the firing. By a simple and easily managed device the direction of the shot can be changed at will by one man, also without interrupting the work of the gun. A second man watches the movement of the cartridge belt, and when one of these is nearly exhausted he bastes on another belt containing 334 cartridges. The cartridges are brought to him by a third man, who also attends to the cooling apparatus, renewing the water as often as necessary. No more than three men are required even for land service. The gun carries four and the limber eight cartridge boxes, making 4,008 charges. The limber is so arranged that it can carry a second tube, both for transportation and action. In this case there is, including ammunition, a total weight of 1,180 pounds. If, however, only a tripod is used, the weight is reduced to 182 pounds, a load which can easily be carried by a pack mule or horse, and, if taken apart, the gun can easily be carried by men for long distances, provided they are relieved frequently. For protection from the fire of the enemy a steel shield is used to cover the sight. If this gun approaches the penetrating power of the Nordenfelt and Hotchkiss rapid-firing guns of the same caliber, it will be a fearful weapon in marine warfare, on account of its rapid action and the number of projectiles that it carries.—*Illustrirte Zeitung.*



THE MAXIM AUTOMATIC GUN.

THE GUN.

WHEN the success of an arm is well established, it is always interesting to make researches into special books and into official reports in order to see what the most authoritative specialists thought of this engine of war at the moment when it timidly made its first appearance. As regards the steel gun, it may be said that it was not spared by their learned predictions. It was for some years declared that it was chimerical, and that it would never be able to satisfy the three conditions that must be exacted of a piece of ordnance, viz., solidity, range, and accuracy. But the time of such discussions has passed, for to-day, save for coast artillery, steel is universally employed for the guns of all calibers in service upon war ships.

We have said in our study upon armor plate, and we repeat it here, that it is in seeking the means of piercing armor plate that the artillery service has been led to change its direction, its gun metal, and its powder. It has thus revolutionized a science which has remained nearly stationary from the origin of firearms up to a recent epoch. In fact, during the Crimean war, the land and sea artillery were still employing nothing but smooth bore guns, which were loaded at the muzzle and which fired round balls. The largest caliber in service upon the ships of our fleet was $7\frac{1}{2}$ inches, and this was called the "50 gun," because its projectile weighed 50 lb. It was in the year 1855 that the first rifled guns appeared, in small number, with two grooves, and of ordinary cast iron, and of $6\frac{1}{2}$ inches caliber. These were constructed for the Crimean war, but were not finished in time to take part in the operations before Sebastopol. They were utilized in China, where they took an active part in the capture of Peiho and Tourane.

However, this model was quickly abandoned, only six or eight specimens of it were constructed, and the gun that succeeded it—the model of 1858-60—was in reality the first type of rifled artillery that did good service in our navy. This gun had three grooves, and threw an ogival projectile, which was guided in the chamber by means of tenons, and which weighed about twice as much as the round ball of the same caliber. Along with it appeared steel hooping and loading at the breech. However, it must be stated that some pieces of this type were loaded at the muzzle. The powder was always Ripault's, of very fine grain and very brittle, and used in charges of about one-tenth the weight of the projectile. The initial velocity, as a consequence of the increase in weight of the shell, never exceeded 1,200 feet. We had $5\frac{1}{2}$, $6\frac{1}{4}$, and $8\frac{1}{2}$ inches of this model. The $5\frac{1}{2}$ inch gun was loaded at the breech (model of 1858-60), and weighed 8,000 lb. Its 70 lb. projectile had a velocity of 1,040 feet.

The 1858-60 artillery was replaced with a much superior model, that of 1864-66, which formed the true armament of our first armor-clad fleet. The 1864-66 guns, some of which still exist, were of hooped cast iron and were loaded at the breech. The type comprised calibers of $5\frac{1}{2}$, $6\frac{1}{4}$, $7\frac{1}{2}$, $9\frac{1}{2}$, and 11 inches. According to their caliber, these pieces were rifled with three or five parabolic grooves. With the 1864-66 type appeared the great weight of artillery and the bursting balls designed for piercing armor plate. The $9\frac{1}{2}$ inch gun weighed 32,000 lb., and the 11 inch weighed

45,200. The idea of handling and supporting such imposing masses as these upon a movable platform like the deck of a ship did not fail to frighten naval officers, who up to that time had been accustomed to use nothing but relatively light artillery. Very many others have since been seen, and to-day great weights no longer scare any one, thanks to the mechanical devices that have been invented.

The 1864-66 gun threw massive balls, some of them cylindrical and others ogivo-cylindrical, and of a weight triple that of the round ball. It threw, likewise, oblong shells of ordinary cast iron weighing twice as much as the same ball, and, finally, canister shot. The charge of powder was about one-sixth of the weight of the projectile. The initial velocity was 1,075 feet for the massive ball and 1,180 for the shell. The 5½ inch gun threw shells only. The old Ripault powders were always used, but these were soon to disappear.

The artillery of the model of 1870 marked a further step in advance. It was always of hooped cast iron, but it was tubed. It comprised calibers of 5½, 6¼, 7¼, 9½, 11, and 12½ inches. They consisted of a cast iron body, of a tube, and of hoops. The tube was of cast steel and had a thickness of about ¼ caliber. The posterior part of the tube, in which a recess for the breech was formed, was of a wider diameter than the rest of the tube. The tubed portion extended to about three calibers beyond the point of the projectile at its position of loading. The tube was connected with the body of the gun by a threading.

The steel hoops, placed in one or two rows, according to the caliber, covered a length of about nine calibers. Finally, for the first time, there was applied to these pieces the method of firing through a vent in the axis of the screw breech with obturating quick matches. The number of rifling grooves, after some tentatives, was fixed definitely at twice the number of inches of the caliber. The powders adopted were no longer the Ripault fine-grained brittle ones, but slow and large-grained powders that were obtained from the Wettern works of Belgium before they were manufactured in France by the navy.

Upon the whole, the 1870 artillery is characterized by the combined use of steel hooping with cast iron, by the increase in the number of grooves of the rifling, by the forcing of the projectiles by means of copper collars, and by the regular putting in service of slow powders.

The artillery had evidently made considerable progress, but it saw that it was arrested in its forward march by the metal—cast iron—that it was using for the body of its ordnance. It was then that, starting from its direction of 1870, it reached the gun of 1875, the first steel model of the artillery of the French fleet.

The reasons why steel alone was adopted for the construction of ordnance were as follows. This metal has a very high limit of elasticity, that permits it, without permanent distortion, to withstand the enormous pressure developed by powder. Moreover, the bursting charge is quite remote from the limit of elasticity, and hence a greater security in the use of it; for, before the resistance to bursting, under the action of abnormal pressure is reached, the metal, through its distortion, is capable of storing up a large amount of work, and this is a guarantee against the chances of accidents.

Finally, the permanent elongations that this metal undergoes when it is submitted to stresses superior to its limit of elasticity are the cause of every abnormal pressure showing itself by traces of strain, such as the enlargement of the chamber—elongations that will avert danger. We may add that steel, properly tempered, possesses both a great resistance to shock, which permits it to support the violent action of powder gases, and great hardness, which prevents the wear of the chamber by the projectiles. But at the epoch at which the first 1875 guns were constructed, the manufacture of steel was not as perfect as it now is. During the last decade, metallurgic processes have made immense progress. However, it was not merely technical considerations that pushed the artillerists of the navy ahead in their campaign against the adoption of steel as a gun metal; for, although some said that such a measure was premature, others allowed themselves to be guided more especially by an argument of a different nature. Thus the 10¼ inch gun, model of 1870, of cast iron, hooped and tubed, cost but $5,554, while the same gun of steel, model of 1875, cost $21,540. It may be admitted that fifteen years ago steel ordnance cost three or four times more than that of cast iron. It is starting from such a consideration that cast iron still prevails as mistress in coast batteries.

The artillery of the 1875 model, the first steel ordnance of our armament, comprised calibers of 4, 10¼, and 13¼ inches. They were tubed and hooped like the model of 1870.

In the 10¼ inch No. 1, and in the 13¼ inch, the tube extended throughout the whole length of the chamber properly so called, but the recess for the breech did not form a part of it—an arrangement that was found defective and that experience caused to be modified.

It will be recalled that it was one of the 13¼ inch guns of this model that burst last December on board the Amiral Duperre.

At the first moment, everything was suspected—metal, shape, and powder. The past was incriminated, and it is said that even the pressure was recalled that was exerted upon the naval artillery in order to decide it prematurely to abandon cast iron, which was giving it entire satisfaction.

We shall not enter into a discussion of the facts, which have a retrospective interest only; we shall be content to assert that if the partisans of cast iron had been listened to, we should be in a somewhat unenviable position and behind all the other powers, while the rank that we now hold is most honorable. With cast iron, we were revolving in a vicious circle; steel has allowed us to progress, and responds to the legitimate exigences of artillerists. Moreover, as regards the gun of the Amiral Duperre, although it is true that the metal did not present the same qualities as that which is now being made, it is none the less true that the accident was due to the powder. This latter, supercharged in badly established storerooms, became brittle, and recent experiments have demonstrated that the normal pressure must have increased, at the time of the catastrophe, by about a thousand atmospheres.

In the guns of the 1875 model, the initial velocity of the projectile of the 13¼ inch is 1,590 feet with the chocolate powders in use. The projectile weighs 925 lb. But the patterns of these guns were later on modified so that charges nearly equal to a third of the projectile might be used, and that the initial velocity of the balls might be raised to about 1,640 feet, without exceeding pressures of from 2,600 to 2,800 atmospheres on the breech, according to the caliber.

Later on still was constructed the model of 1875–79, which is characterized by a length of chamber of 28 calibers, which permits of using a charge of powder equal to half the weight of the ball. In this way, slightly greater initial velocities are obtained.

We have 10¼, 13¼, and 14½ inch guns of this model. The 14½ inch weighs 167,200 lb. As for the 16¼ inch, which is in service on the Indomptable type of armorclads, that is of the model of 1875; but this caliber has been replaced with the 14½ inch model of 1875–79.

After this comes the 1881 ordnance, which is distinguished from the preceding by the elongation to 30 calibers and the increase of the charge and of the velocity, which reaches 1,700 feet. Then comes the model of 1884, of 40 calibers, in which the thickness of the elements ought not to exceed 5½ or 6 inches. The velocity is 1,970 feet. In these pieces, very slow powders and charges of ⅗ of the weight of the projectile are employed.

As a last form, we have the 1887 model, in which the length is carried to 45 calibers. With the new "fagot" powder, the initial velocity will reach 2,625 feet. Up to the present, only 5½, 7¼, and 13¼ inch calibers of this type of artillery have been constructed.

The rapid *expose* which precedes permits of following the progression of our naval ordnance. In less than twenty years, the initial velocities have been doubled, and the calibers have increased, passing from 10¼ to 17¼ inches to descend to 13¼ and 14½ inches. The efficiency of a piece of ordnance does not depend upon its caliber solely. It has been deemed useless in France to strive to have guns of large chamber diameter. Although 17¼ inch ones have been made, a halt was soon called in this direction in order to fall back upon smaller calibers. The English have imitated us, for after their 16¼ inch guns weighing 111 tons, designed for some of their new armorclads, they have fallen back to 68 tons for the Nile and Trafalgar, now afloat, and they propose to put 63 ton ones on the monster armorclads of 14,000 tons that they are going to put upon the stocks.

But how are these guns constructed? What is the system in France?

Ruelle, who, with the Nevers foundry, formerly constructed the naval cast iron guns, has reserved to himself the manufacture of the cast iron bodies of the coast artillery; but, for the steel tubes and hoops of these pieces, as well as for all the elements that concur in the formation of all steel guns, these works address themselves to the trade. The tubes, bodies, hoops, etc., of the steel guns are therefore made in our metallurgic establishments under the surveillance of the state comptrollers.

Ruelle tests them, finishes them, and puts them together—all operations of very minute detail which must be performed with particular care. So, taking administrative formalities and the exigences of the control into account, it takes more than eighteen months to complete a gun of large caliber.

The Creusot works, which are large producers of steel, have, as may well be thought, taken an important position in the manufacture of the elements of steel guns and of the pieces of the same metal that strengthen the cast iron ordnance designed for the armament of coast batteries. They have not stopped there, but have constructed complete guns, and, in recent years, have adopted patterns that are all their own.

Thus, we may remark that the artillery service of the works, between 1875 and 1889, delivered to the French navy the parts in a rough state of 319 all-steel guns, and, among these, 82 four and a half inch pieces, 36 five and a quarter inch pieces, 13 ten and a half inch, 22 thirteen and a quarter inch, and 4 fourteen and a half inch.

The steel generally employed for ordnance is manufactured in the Martin-Siemens furnace. The charge of the furnaces is about 20 tons, and consists of a proper mixture of cast iron and pure iron. The operation takes about twelve hours. Its course is watched and samples are taken from the furnace and at once forged, and an examination of their fracture permits of judging of the nature of the metal.

The molten metal is drawn off into a ladle and poured into the ingot moulds. In order to obtain ingots of a weight greater than 20 tons, it is necessary to use the metal furnished by several furnaces. To this effect, the contents of each furnace are drawn off into a ladle carried by a car which is led by iron tracks over a deep pit in which is placed the ingot mould that is to receive the contents of each ladle. Then comes the forging. The object of this is twofold: (1) to secure in the piece that cohesion which the cast ingot does not possess with regularity from the exterior to the center; and (2) to give, in the same section, that regularity of structure which results in a homogeneousness of the metal, which is shown by a greater increase in resistance and elongation.

The ingot is taken from its mould, after cooling, and is then fixed to a maneuvering bar and put into a reheating furnace.

When it has reached the proper temperature, it is placed under the power hammer, where it undergoes the first forging operation, called "hammering" or "drawing out," and in which an octagonal section is given to it.

Then, in another operation, called "swaging," which embraces several heatings and reheatings in succession, the definite form is given to the hammered piece that it is to have in order to be put in the lathe. The number of heatings that a piece undergoes before being finished in the forge is variable and depends upon its weight and dimensions.

In the course of the forging, the upper and lower extremities of the ingot are cut off, these not being perfect enough, as a general thing, to be used in the manufacture of the parts of a gun. These cut-off parts are called, in French parlance, "chutes." The navy requires a minimum "chute" of four per cent. at the bottom and of 28 per cent. at the top of the ingot.

The ingot having been heated successively in its various parts in order to finish the shaping of it (that being on account of its great length), there result inequalities of molecular tension in the mass that it is necessary to cause the disappearance of, in order to secure a perfect homogeneousness of the piece. This is effected by the operation of annealing, which consists in a heating of the entire piece to a cherry red, with particular precautions for securing a regular cooling throughout its entire length. Afterward, a piece is removed from each extremity, from which a certain number of test bars are cut. One of these bars is submitted to tractive tests, and gives the quality of the metal in its present state. The other bars are not tested for traction until they have been tempered in oil at different temperatures, in order to permit of judging of the temperature at which the piece itself must be tempered.

After the tests, before tempering, the rough forging is turned and bored in order to bring it to dimensions very close to its final ones. For boring two drills, operating in opposite directions, form a tubular cavity in the piece, but leave a core in the center which can be utilized afterward and which gives valuable information as to the defects that may exist in the center of the ingot.

In pieces of medium and large caliber, the boring is followed by another annealing, which is more efficacious than the first, on account of the central space left by boring. The rough-dressed piece must afterward be tempered. To this effect, it is suspended in a vertical furnace, in which it is heated and at the same time given both a rotary motion around its axis and a motion in the direction of the latter so as to obtain a very uniform heating. When the temperature that the tests before tempering have shown to be most favorable is reached, the door of the furnace is opened and the tube is quickly plunged into an oil well. The tempering gives the metal homogeneousness and increases its tenacity and hardness. The wells that serve for the tempering of gun tubes of large caliber are no less than 130 feet in depth.

Whatever be the care taken, heating for tempering can never be of absolute regularity. It is therefore necessary, after tempering, the same as after forging, to submit the gun to an annealing process which differs from the first only in the temperature at which it is effected, and which is lower than that at which the tempering is done.

After the cooling, tests are made in order to see whether the metal fulfills the conditions required by the contract. The test pieces are greater in number than they are for the preliminary tests before tempering. In addition to tractive tests, the metal is submitted to impact tests, and, as regards the smallest calibers, to tests of flexion.

Finally, as the preceding tests are made only with specimens removed from the two extremities of the tube, and are incapable of furnishing any data as to the nature of the metal in the center of the piece, the latter, after it has been bored out to a diameter slightly less than it is finally to have, is submitted to a test with powder, comprising three shots, one at each extremity and one at the center of the tube.

(To be continued.)

THE MERSEY TUNNEL RAILWAY.

The road is constructed almost entirely in tunnel of double track width, and the tunnel is lined throughout with brick in cement. The road begins at the central station of the Cheshire lines in Liverpool, and, from James Street station, passes in a direct line under the bed of the river Mersey to Birkenhead. Under the river, which is three-quarters of a mile wide, the tunnel is in sandstone rock, with an average cover of 30 to 35 ft. between the top of the tunnel and the river bed. The lowest rail level is 145 ft. below mean high water mark. The gradients therefore are somewhat severe, being, on the Liverpool side, 196 ft. per mile. The drainage of the tunnel is dealt with in two pumping shafts, one on each side of the river, the water draining to the shafts through drainage headings beneath the tunnel. The pumps raise the water 170 ft. There are three pumping engines on each side of the river, for which both the walking beam and the horizontal types of engines have been adopted. The tunnel is ventilated by four large Guibal fans kept constantly at work. They exhaust from a heading or gallery 7 ft. 2 in. diameter, running parallel with the tunnel, into which there are frequent openings with sliding doors, so that the exhausting action of the fans can be distributed or concentrated at pleasure. Fresh air is supplied to the main tunnel at the stations. By this ventilating system the noxious gases are so diluted that they are rendered harmless and practically imperceptible at every point, and the tunnel is far better ventilated than most stations and public buildings in the vicinity.

Powerful hydraulic lifts are provided on each side of the river for raising passengers from the underground station platforms to the street level 100 ft. above. The power for these lifts is taken from tanks placed in lofty water towers, which form striking architectural features of the riverside stations. The tanks are kept full by small pumping engines, the same water being used over again in continuous circuit. At present James Street station, Liverpool, is used as a temporary terminus pending the completion of the station and connections at the central station.

The following facts are of interest:

Permanent Way.—Steel rails, "bullhead" section, 82 lb. per yard; chairs each 52 lb.; sleepers spaced 2 ft. 3½ in. center to center.

Rolling Stock.—Weight of locomotives in working order, 70 tons; cylinders 21 in. diameter by 26 in. stroke; driving wheels, six-coupled, 4 ft. 6 in. diameter; cars lighted with Pintsch's compressed oil gas; rolling stock fitted with vacuum automatic continuous brakes.

Pumping Machinery.—Compound walking-beam engines, 200 horse power; cylinders, 36 and 55 in. diameter; pump rams, 40 in. diameter by 15 ft. stroke; compound horizontal engines, working either double-lifting or bucket pumps in balanced sets from quadrants.

Ventilating Machinery at Shore Road.—Condensing compound engine of 120 indicated horse power; revolutions, average per minute, 45; fan, 40 ft. diameter, by 12 ft. wide; exhausting about 200,000 cu. ft. of air per minute.

Hydraulic Lifts.—Rams of steel tubes in 12 ft. lengths, screwed together; external diameter, 18 in.; thickness one-half inch; average pressure, 90 to 100 lb.

per sq. in.; average speed of lifts, 150 ft. per minute; cages accommodate 100 passengers each lift; about five-sixths of the weight of cages and rams is balanced; cages are lighted by ordinary gas, fed through flexible tubes.

Traffic.—About 300 trains pass through the tunnel per day. Present maximum service, one train each way every five minutes. The largest number of passengers yet carried in one day, 52,000, but the carrying capacity of the tunnel has not yet been fully tested.

BULL ROCK LIGHTHOUSE, SOUTH COAST OF IRELAND.

ANOTHER new and powerful guiding light has been placed on British land to guide the mariner to our shores and ports. On the 26th of June last the Bull Rock light was exhibited at its full power, and observed at distances varying from fourteen to five miles by Sir E. H. Kinahan, Bart., and Commander A. G. R Ryall, R.N., Commissioners of Irish Lights; Sir R. S. Ball, K.B., LL.D., Astronomer Royal of Ireland, their scientific adviser; and Mr. W. Douglass, M.I.C.E., the engineer to the commissioners. The atmosphere was misty and unfavorable for distant observation, but at eleven miles the effect was very fine, as the passing mist was brightly illuminated by the flashes from the light at full power. On the following night it was observed at distances varying from sixteen up to twenty-three and a half nautical miles, when it dipped below the horizon. As the commissioners wished to exhibit this light at an early date, it was lighted on January 1 by using a single burner and one tier of lenses, equal to a maximum power of 217,994 candles; the second tier of lenses has now been added, which increases the power—when worked in biform—from 69,485 candles during clear weather to 435,988 candles during fog, and making it the most powerful light on the Irish coast.

The Bull Rock is situated off the entrance to the Kenmare River, County Cork, five and a half miles from the mainland and two and a half miles from the nearest point of Dursey Island. Its length is 750 ft., breadth 540 ft.; the sides are steep and rugged and the summit 305 ft. above sea level. It lies N.W. by N. from the base of the Calf Rock lighthouse, the top of which was carried away during the terrific storm of November 26, 1881, fortunately without loss of life. As a substitute a temporary light was exhibited from Dursey Head on February 1, 1882, and continued until the Bull Rock was lighted.

Work was commenced on April 21, 1884, by landing a party of miners, a coil of rope, a few eye bolts, a light spar, and some boring tools. The men climbed the rock with difficulty, dragging the spar with them until a height of 110 ft. was reached. Here a suitable place for fixing derricks was selected, and by the aid of the spar two heavier spars were raised, and fixed there as derricks. After the derricks were fixed two jack-roll winches were landed, and with these and the derricks the workmen's hut—already fitted and marked—water, coal, and provisions were landed. In a short time a few men were established continuously on the rock, who quickly increased the accommodation until it was sufficient for the staff required for the first portion of the work. This consisted entirely of excavation principally for the purpose of extending the illuminated arc to the utmost limit, and also to form sites for tower, dwelling, stores, and gas holders. The total amount excavated and disposed of amounted to 15,957 cubic yards of hard rock. This has caused the work to extend over a longer period than was at first anticipated, as, owing to the uncertainty of landing water and provisions, only a small number of men could be kept constantly on the rock.

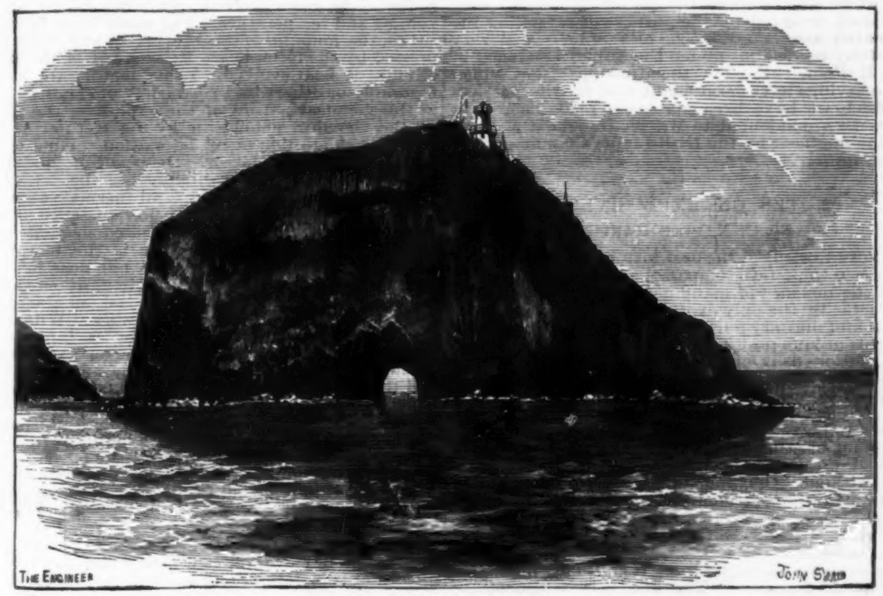
As shown on the plan—Fig. 1—and south elevation—Fig. 2—the station consists of an octagonal tower, 22 ft. high, the center of light being 272 ft. above high water, a dwelling for the lightkeepers, having a mess-room, four bedrooms, a pantry, and storeroom, connected with the tower by a covered passage; a retort house, 28 ft. by 20 ft.; a coke store, including engine house, 29 ft. by 17 ft., with cellar below of the same capacity; two gasholders, each 25 ft. diameter, and each holding 4,600 cubic feet; a fog-signal house, 12 ft. by 9 ft., with arrangement for exploding gun-cotton charges, and a magazine, 10 ft. by 6 ft., for storing the charges. All the buildings are of rubble masonry, in Portland cement with granite dressings. The rubble was selected from the stone quarried to form sites for the buildings, and the granite obtained from Dalkey, near Dublin. The light is a biform flashing light, exhibiting flashes at intervals of fifteen seconds. The illuminating agent is oil gas, on Pintsch's system, consumed in two ten-ring Douglass gas burners. Three rings of flame—the first, fifth, and tenth—are used in clear weather, all the rings of one burner in hazy weather, and all the rings in both burners during fog.

The lantern is circular, helically framed, and 14 ft. diameter. The pedestal is of cast iron, 3 ft. 9¼ in. high, the glazed portion 15 ft. high, and the total height from gallery of tower to top of lightning conductor point, 29 ft. 6 in. It is glazed with three-eighths inch plate glass.

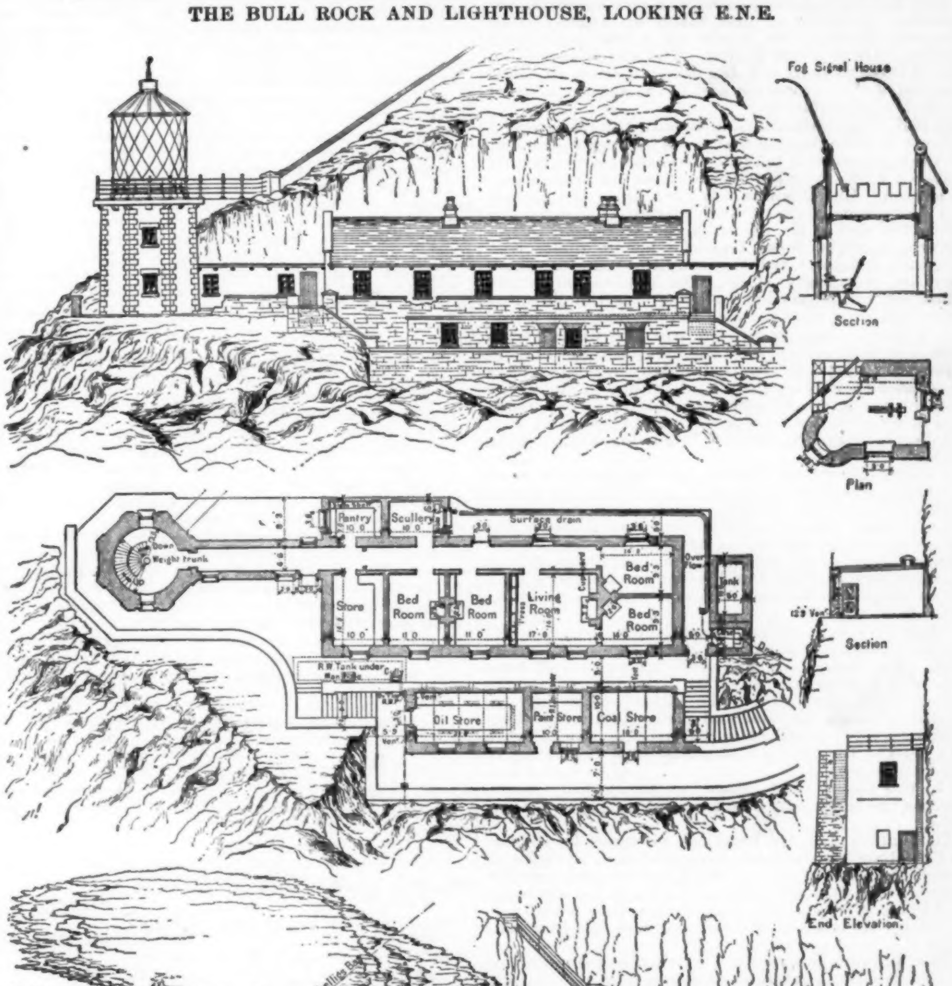
The optical apparatus consists of a circular cast iron pedestal 8 ft. 6 in. diameter, in which is placed the rotating machine, and on its top is fixed a steel roller path 8 ft. 7 in. in diameter, carrying eight steel rollers 7 in. diameter. The rollers support a cast iron table with corresponding roller path, on which is placed two tiers of lenses having a focal distance of 1,330 m.p.m. Each tier is formed of 6 panels 6 ft. 8 in. in height by 5 ft. 3 in. wide. The fog signal is arranged for two explosions in quick succession, at intervals of ten minutes; it is in duplicate, and consists of a light iron jib, with a cross bar at the top 4 ft. long. When working the signal the head of the jib is lowered close to a window in the signal house, through which the operator attaches the 4 oz. charges of cotton powder to each end of the cross bar; it is then raised by pulling a locking lever to a height of 13 ft. above the house, the movement simultaneously opening the cover of a box containing the dynamo, so that the charges can only be fired when the jib is in the firing position. After the first discharge a shunt on the dynamo is moved over, and the second charge exploded. By reversing the lever the cover of the dynamo box is closed, and the jib again placed in position for receiving fresh charges. An electric bell, the sounding of which is regulated by clockwork, warns the operator when the time has arrived for repeating the signal.

To meet the irregular demand for gas, owing to the variable duration of fog, two retort benches are provided, one containing three 5 in. retorts, the other two of 7 in. A ten-wick mineral oil lamp of the same diameter as the gas burners is also provided to be used should the gas supply fail; this is placed on a revolving table opposite to the gas burner and within the dark arc; it can be swung round into position immediately and connected with a reservoir, which is supplied by a force pump from a cistern on the gallery outside the lantern.

The lantern was supplied by Messrs. Grendon & Co., of Drogheda; the optical apparatus by Messrs. Chance



THE BULL ROCK AND LIGHTHOUSE, LOOKING E.N.E.



THE BULL ROCK LIGHTHOUSE.

Brothers, of Smethwick; the oil gas plant by Pintsch's Patent Lighting Company, limited; the gasholders by J. T. B. Porter & Co., Lincoln; the rotating machine by Messrs. Chancellor & Son, Dublin; and the gas and oil burners by Messrs. Edmundson & Co., of Dublin. The prices, exclusive of erection, were, for the lantern, £1,302; optical apparatus, £3,130; oil gas plant, £243 9s. 6d; gasholders, £628; rotating machine, £115 10s.; gas and oil burners, £197 17s. 3d. The total cost of the work, which also includes the quarrying and disposal of the rock removed for the purpose of extending the illuminated arc, was £29,500, and it has been very successfully carried out under the superintendence of Mr. F. R. Foot, C.E. For the drawings from which our engravings have been made, and for the particulars which we have been enabled to place before our readers, we are indebted to Mr. W. Douglass, M. Inst. C.E., the engineer to the Irish Lights Commissioners. —*The Engineer.*

NOTES ON EXPLOSIVES.*

By C. Napier Hake.

Glancing briefly at the past history of the subject, it will be seen that, until comparatively recently, perhaps within the memory of many here present, gunpowder was practically the only explosive in use, both for industrial and military purposes. Although it no longer holds this unique position, it is by no means superseded nor, curious as it may seem, is it likely to be at present. There is certainly no explosive known which lends itself so easily to so many and such varied purposes. To use Mr. Alfred Nobel's words,† "In a mine it is used to blast without propelling; in a gun, to propel without blasting; in a shell it serves both purposes combined; in a fuse, as in fireworks, it burns quite slowly without exploding. Its pressure exercised in those numerous operations varies between 1 oz. (more or less) to the square in. in a fuse and 85,000 lb. to the square in. in a shell. But, like a servant of all work, it lacks perfection in each department, and modern science, armed with better tools, is gradually encroaching on its old domains." The discovery of guncotton, in 1846, was the commencement of a new epoch in explosives. Although at first taken up eagerly by all European governments, it was for a time abandoned after 20 years of severe testing. The disastrous experience of these 20 years was due to an imperfect chemical knowledge of its properties and to the absence of good methods of manufacture.

In 1847, almost simultaneously with the discovery of guncotton, nitroglycerin first made its appearance, but for the same causes it fell into disrepute, leaving behind it even a worse record of disaster than its predecessor, guncotton. But this was only for a time; the patient and courageous labors of Sir Frederick Abel as regards guncotton, and of Mr. Alfred Nobel as regards nitroglycerin, brought these powerful agents under control, and demonstrated the conditions under which they are chemically stable; the application of the principles of detonation to them was the finishing touch to a great work. Since that period, and up to the present time, guncotton and the nitroglycerin class of explosives have held the first position wherever a powerful agent is required. Many attempts have been made to displace them, and yet one cannot at the moment point to any serious competitor; but a vast field of research has been opened, and there is no lack of laborers adding day by day to our knowledge of the subject.

Leaving history, and before entering upon the more practical portion of my paper, I should like to glance briefly at the theory of the subject. Let us consider for a moment what is meant by the term explosive. An explosive may be defined as any solid or liquid substance or compound which on the application of heat or shock becomes very rapidly converted, either wholly or partially, into the gaseous state, with the evolution of heat.

Explosives may be conveniently divided into two classes, generally known as "high" and "low" explosives. The former are the more powerful, and their explosion is usually effected by "detonation," and is, consequently, very rapid; the latter are usually exploded by simple ignition, and their explosion proceeds progressively by combustion. Dynamite may be taken as a type of the former and gunpowder as a type of the latter class. It is, however, not easy to hold strictly to this classification, since, under certain circumstances, the terms may become practically interchangeable.

Detonation may, for practical purposes, be defined as the (almost) instantaneous resolution of an explosive into other forms of matter, chiefly permanent gases occupying many times the original bulk of the explosive, and hence exerting enormous power; it is usually induced by the ignition of an explosive of the fulminate class.

In examining an explosive, its chemical composition should first be ascertained, and from this, in the light of our present experience, it is possible to draw many inferences, such as, for example, the products of its decomposition, the quantity of heat and the nature of the gases evolved, its probable effectiveness as an explosive, its stability, and its sensitiveness to concussion and friction. To arrive at its chemical composition presents, comparatively speaking, the least difficulty. It is not so easy to arrive at a correct conclusion as regards its products of decomposition. What is specially required is the equation of its decomposition under conditions most favorable to the production of the maximum effect as an explosive; from this equation may be calculated according to well known laws the quantity of heat evolved by the decomposition and the volume of gases produced. But the many and varying conditions which influence the mode of decomposition of different substances, the difficulty of determining high temperatures with accuracy, the complication of thermo-chemical laws, and many other considerations, interfere with the absolute correctness of the result. Nevertheless, a very fair relative one is obtainable. Chlorate of potassium and nitrate of ammonium are examples of varying decompositions of certain compounds under varying conditions, the latter being capable of decomposition in no less than seven different ways.

To determine the theoretical effectiveness of an explosive it is necessary to know two things:

1st. The volume and temperature of the gases evolved.

2d. The quantity of heat evolved by the chemical change occurring during the explosion.

The effectiveness of an explosive is dependent on the volume of the gases evolved, the amount of heat generated, and the rapidity of the explosion. The pressure is due to the gases evolved, and is dependent on their volume and temperature. The work done is dependent on the amount of heat evolved, and may be expressed by the formula 423 M, where M is the number of units of heat evolved. These factors are modified favorably or otherwise by a variety of conditions, such as the chemical nature of the explosive, the rapidity of the chemical change, or by the method of firing, whether by ignition or by detonation. Time is therefore an important factor. Dissociation modifies the effect of an explosive by diminishing the initial pressure, but does not affect the total thermal value, as the heat which is absorbed in the first instance is reproduced by the union of the dissociated elements as the temperature falls. The pressure is the factor which produces rupture of the envelope, but does not necessarily produce any extended mechanical effects, such as smashing or dispersion. This last, as already said, represents the heat equivalent or work. What may be termed the "power of an explosive" is influenced by the rapidity of the chemical change on explosion, and of two explosives evolving the same amount of heat, and therefore the same amount of work, that explosive which is the more rapid does that work in a shorter time, *e. g.:* Fifteen tons lifted 1 foot high represents the same amount of work done, whether we do it in a second, a minute, or an hour; but the power necessary to do it in one minute we call a horse power; if we wish to do it in a second, we require 60 horse power.

Further, rapidity of detonation, or the velocity of propagation of what Berthelot has termed the "explosive wave," is another important consideration. An illustration of the difference with which the velocity of molecular transformation can be transmitted is exemplified by the behavior of blasting gelatine, for instance, under various circumstances. If we light a small portion, it smoulders away. On the contrary, if more strongly heated, it burns more rapidly, but in both cases the combustion proceeds at a slow rate from layer to layer, and the mechanical effects are *nil* when unconfined. If we detonate a similar cartridge, also unconfined, the results are very different; great mechanical effect is produced, because the decomposition is almost instantaneous. In fact, the detonation is transmitted with enormous rapidity throughout the entire mass.

The actual velocity of the explosive wave has been measured, and has been found to be from 5,000 to 6,000 inches per second for guncotton, and about 5,000 meters per second for dynamite. At this rate the explosion of a cartridge a foot long would only occupy $\frac{1}{12000}$ part of a second, while a ton of dynamite cartridges about ⅝ diameter, laid end to end, and measuring one mile in length, would be exploded in one quarter of a second by detonating a cartridge at either end.

The theoretical efficiency of an explosive cannot in practice be realized in useful work for several reasons, as, for instance, in blasting rock:

(1.) Incomplete combustion.

(2.) Compression and chemical changes induced in the surrounding material operated on.

(3.) Energy expended in the cracking and heating of the material which is not displaced.

(4.) The escape of gas through the blast hole and the fissures caused by the explosion.

The useful work in blasting consists partly in shattering the rock and partly in displacing the shattered masses. The proportion of useful work obtainable from the employment of explosives has been variously estimated at from 14 to 33 per cent. of the theoretical maximum potential. For the purposes of comparison it does not matter whether we take the theoretical or practical efficiency of an explosive, since these stand in the same relation to one another, as will be seen from the following tables:

MECHANICAL EQUIVALENT OF EXPLOSIVES.

Roux and Sarrau.

	Theoretical work in kilos.	Relative value.
Blasting powder with 62 per cent. KNO_3	242,335	1·0
Dynamite with 75 per cent. nitroglycerin	548,250	2·26
Blasting gelatin with 92 per cent. nitroglycerin	766,813	[illegible]·16
Nitroglycerin	794,563	[illegible]·28

Relative value of—

Dynamite	1·0
Blasting gelatin	1·4
Nitroglycerin	1·45

In this connection the following records are also of interest:

	Dynamite.	Blasting gelatin.
St. Gothard railway	1·0	1·46
Zaukeroda mine	1·0	1·45
Tarnowitz excavation	1·0	1·41
Mansfelder "	1·0	1·33
Mean	1·0	1·41

Experiments made in lead cylinders gave the relative value of—

Dynamite	1·0
Blasting gelatin	1·4
Nitroglycerin	1·4

The stability of an explosive is of first importance. Decomposition may occur either spontaneously or through the aid of some foreign agency. The stability of an explosive is dependent on:

First. Its chemical constitution.

Secondly. Its freedom from certain impurities.

Some explosive compounds when properly manufactured show no tendency to decompose under ordinary conditions, as, for example, nitroglycerin or guncotton. Conditions which influence the neutrality of these explosives, however, are favorable to their spontaneous decomposition.

A solution of dinitrobenzene in fuming nitric acid, though a very powerful explosive, and not dangerous in itself as regards liability to decomposition, would be a source of danger to certain other explosives stored with it, in so far as their neutrality would be endangered by the absorption of acid fumes.

As an instance of spontaneous decomposition of two compounds, in themselves fairly stable, may be noted chlorate of potassium and nitrate of ammonium. These two powerful oxidizing agents react rapidly on each other with the evolution of chlorine compounds, and in the presence of a combustible and under otherwise favorable conditions the heat evolved is sufficient to cause explosion. Again, experience has shown that nitrate of ammonium and guncotton are more or less incompatible owing to a tendency to spontaneous decomposition. Sulphur and iron or sulphur and zinc, when mixed together under favorable conditions, react on each other with evolution of heat sufficient to ignite gunpowder, and this has actually occurred in firework compositions.

For these reasons explosives which from the nature of their constitution have a tendency to generate or evolve acid fumes, or otherwise possess elements of an objectionable nature as regards their influence on stability, are dangerous.

Sensitiveness to concussion or friction or to ignition is another form of expression for instability under somewhat different conditions. The two are, however, very much governed by the same laws. Broadly speaking, the sensitiveness of an explosive as of any chemical substance is directly as the heat evolved by its decomposition and inversely as the temperature of its decomposition. A chlorate mixture is therefore more sensitive than a nitrate mixture. The law is, however, modified by the physical character of the explosive substance; for instance, fulminate of mercury in a finely divided state is extremely sensitive to concussion or friction, yet large crystals of the same material are far more sensitive to the same treatment. Elevation of temperature tends as a rule to increase the sensitiveness of an explosive; yet blasting gelatin becomes more sensitive to concussion and friction when in a frozen condition.

I will conclude these theoretical considerations by one more reference to detonation. As before stated, the usual method of ignition employed for low explosives, of which gunpowder is a characteristic type, is a fuse. "High" explosives, on the other hand, are almost always detonated. The best agent for this purpose is found to be fulminate of mercury, and there are special theoretical reasons why this should be so. Fulminate of mercury possesses the following composition, $C_2N_2HgO_2$, and yields on detonation $(CO)_2,N_2Hg$. It explodes at a temperature of 360° F. It is also readily exploded by concussion or by friction, such as scratching it with a pin or by contact with strong nitric or sulphuric acid. It appears, therefore, that no compound liable to dissociation is formed, and therefore no influences exist which would tend to moderate the expansion of the gas and diminish the violence of the initial shock. Generally speaking, one may say that it is neither the volume of gases disengaged nor the heat evolved which gives to fulminate of mercury its peculiar character or special advantages, for it is surpassed in both these directions by many other explosive bodies. Its superiority is demonstrated best when in close contact with an explosive, and its effectiveness is due to three causes:

First. Its nearly instantaneous decomposition by simple inflammation, even when but slightly confined.

Secondly. The almost total absence of dissociation products.

Thirdly. Its great density.

By reason of these conditions the definite products of the reaction appear to form all at once before the gases have had time to expand to a volume greater than that of the original solid.

Passing on to a more practical consideration of the subject, I do not propose to dwell on explosives generally, but only to describe such as are actually in practical use. Those wishing to know what has been suggested in the past with regard to explosives would do well to consult Major Cundill's "Dictionary of Explosives."* In this valuable little book between 300 and 400 suggestions for explosive mixtures are recorded and fully described.

The following table is taken from this work and shows the mode of classification and the number of varieties of each class:

	Varieties.
Gunpowder	16
Nitrate mixtures other than gunpowder	63
Chlorate mixtures	67
Nitro compounds containing nitroglycerin	82
Guncotton and other nitro compounds	64
Picric powders	11
Sprengel explosives	5
Miscellaneous explosives, includ. fulminates	40

Many of these are mere chemical curiosities, and the large majority, for some reason or other, have never advanced beyond the experimental stage.

Looking at this table, it is obvious that gunpowder no longer retains its supreme position. It is, however, still largely used for mining purposes, especially where a slow explosive is required.

Modern activity in the invention of new explosives has no doubt broken through the monopoly which gunpowder so long enjoyed, but it has also brought forth many new and valuable improvements both as regards the composition and manufacture of this explosive.

I am aware that gunpowder deserves far more attention than I am able to give it in this paper; but its new varieties are so numerous and its application so

* Read before the London section of the Society of Chemical Industry, May, 1889. From *The Journal.*

† On Modern Blasting Agents, by Alfred Nobel, 1878.

* A Dictionary of Explosives, by Major Cundill, R.A.H.M., Inspector of Explosives. Royal Artillery Institution, 1889.

varied both for civil and military purposes, that it would be impossible to enter into detail in an essay of necessarily restricted length without excluding matter of, at the moment, greater interest.

In Major Cundill's "Dictionary of Explosives" 67 chlorate mixtures are described, and of these only one, to my knowledge, has been authorized. In the report of her Majesty's Inspectors of Explosives for 1886, Dr. Dupre, F.R.S., who from his long connection with the Explosives Department has an exceptional experience as regards the properties of explosives, says as regards dangers in the use of chlorate of potassium:

"Chlorate of potassium, on account of the readiness with which it lends itself to the production of powerful explosives, offers a great temptation to inventors of new explosives, and many attempts have been made to put it into practical use, but so far with very limited success only. This is chiefly owing to two causes. In the first place, chlorate of potassium is a very unstable compound, and is liable to suffer decomposition under a variety of circumstances, and under, comparatively speaking, slight causes both chemical and mechanical. All chlorate of potassium mixtures are liable to what is termed spontaneous ignition or explosion in the presence of a variety of materials, more especially of such as are acid; and all chlorate mixtures are readily exploded by percussion, such as a glancing blow, which might easily and would often occur in charging a hole. In the second place, there is some evidence to show that this sensitiveness to percussion and friction increases by keeping, more especially if the explosive is exposed to the action of moist and dry air alternately. If inventors would only keep these characteristics of chlorate mixtures in mind, they would frequently save themselves serious disappointment."

The picric powders are few in number, and form a subdivision of the great nitro compound class. With the exception of picric acid itself, no practical importance can at present be attached to this class of explosives. The fact that picric acid without the addition of oxidizing agents forms a powerful explosive when fired by a detonator was pointed out by Dr. Sprengel, F.R.S., in 1873, in his well known research on a "New Class of Explosives." It is supposed to form an ingredient of the French military explosive melinite, the composition of which is kept secret. In 1885, M. Turpin patented the application of picric acid as an explosive for military and other purposes. Its comparative inertness under ordinary conditions and high density (1·6) give it certain advantages as a filling for shells. For blasting purposes, however, it has the objection that it gives off actively poisonous gases and forms carbonic oxide on combustion, owing to a deficiency of oxygen in its composition.

In consequence of a disastrous explosion * which occurred at a chemical factory near Manchester, and which was brought about by the accidental mixing of picric acid and litharge in a molten state during a fire, picric acid has, by an order in council, been brought within the scope of the explosives act as regards manufacture and storage, except when—

"(a.) It is wholly in solution.

"(b.) When it is not wholly in solution, but is being manufactured or stored in a factory, building, or place exclusively appropriated to the manufacture or storage of picric acid, and in such manner as effectually to prevent any picric acid from coming into contact (whether under the action of fire or otherwise) with any basic metallic oxide or oxidizing agent, or other substance capable of forming with picric acid an explosive mixture or explosive compound, or with any detonator or other article capable of exploding picric acid, or with any fire or light capable of igniting picric acid.

"Moreover, all picrates or mixtures of picric acid with any basic metallic oxide, etc., as detailed in (b) are to be deemed explosives within the meaning of the act for all the purposes of the said act unless such picrates or mixtures be wholly in solution."

Although from the above list of explosives the number appears large, the number in practical use in this country is very small, and may be taken under three headings, namely:

1st. Gunpowder.
2d. Guncotton and other nitro-compounds.
3d. Nitro-compounds containing nitroglycerin.

The explosives included under the Sprengel class, although repatented from time to time by various "inventors," appear to be all covered by Dr. Sprengel's original patents Nos. 921 and 2,462, 1871. For practical reasons bearing on the safety properties of this class of explosives, none of its varieties has been authorized in this country. Dr. Sprengel's researches, however, must be looked upon as most valuable contributions to our knowledge of explosives generally, and there can be but little doubt that the new class of explosives, of which bellite is a typical representative, is more or less the outcome of these researches.

Guncotton is essentially a military explosive. In the compressed form its density is about 1·0, and, when properly manufactured, it shows no tendency to decompose. When wet it is non-sensitive to ordinary concussion or friction. It may, however, be exploded by a dry primer of the same material, even when saturated with water. For these reasons it possesses special advantages for all military and naval operations in which a violent explosive is required. But for the discovery of nitroglycerin, guncotton would, no doubt, have played an important role in mining operations. In this direction, however, it has not kept pace with its development and utilization for war purposes. Its chief objection for blasting purposes is that it is deficient in oxygen, the disengaged products of the explosion containing large quantities of carbonic oxide (28·5 per cent.) This particular drawback has been overcome by incorporating with it nitrate of potassium or nitrate of baryta, the oxygen contained in these salts effecting a more complete combustion, and rendering the resulting gases less obnoxious than those resulting from pure guncotton. Special preparations in this direction have been introduced under the name of "potentite," "tonite," etc., and are used with considerable success as blasting agents.

Nitroglycerin compounds, however, take the first rank as blasting agents, their superiority lying chiefly in their cheapness, greater strength, and density. The manufacture of nitroglycerin is a comparatively simple process, and is fully described in technical works. The features of the process which are of the greatest importance are the purity of the glycerin, strength of the acids, and the complete washing of the finished product. Rapidity of working depends largely on the strength of the acids, since the heat evolved is least when the strongest acid is employed. The output is increased, the action goes on more uniformly, and is more easily controlled.

Pure nitroglycerin (nitroglycerol) is a colorless mobile liquid possessing a definite composition. Its specific gravity is 1·6 at 60° F. When ignited in small quantities, it burns slowly away. When heated, however, to a temperature of 370° F. it explodes with great violence. When spread in thin layers it is extremely sensitive to slight concussions or blows. At a temperature of 40° F. it takes the crystalline form, and becomes solid and contracts one-twelfth of its volume. In this condition it is far less sensitive to blows and concussions than in the liquid form.

One liter of nitroglycerin produces, when exploded under the most favorable conditions, a volume of gas equivalent to over 10,000 liters. The application of nitroglycerin, or of any liquid or semi-liquid compound, or mixture of the same, as an explosive agent, has been almost universally abandoned, and in this and most other countries even prohibited.

Nitroglycerin enters into the composition of a very important class of explosives, possessing the generic title of dynamite. A very large number of such exist under various fancy names, but for convenience they may be divided into three classes, namely:

1. Dynamite in which nitroglycerin is alone the active principle; a chemically inactive material, such as kieselguhr, being used merely as an absorbent, as, for example, in ordinary dynamite No. 1.
2. Dynamite in which the absorbent used is, in itself, an explosive or combustible, such as, for example, "Atlas powder." This class of dynamite is little used in this country.
3. Dynamite in which the liquid character of the nitroglycerin is destroyed by gelatinizing it by means of guncotton, with or without the addition of oxidizing agents.

The ordinary dynamite of commerce as used in this country is a mixture of 75 parts by weight of thoroughly purified nitroglycerin with 25 parts by weight of a porous infusorial earth known as kieselguhr, and consisting mainly of silica. In the case of kieselguhr dynamite, detonation is the more readily effected, and the combustion is more complete, the more nearly the absorbing power of the kieselguhr is satisfied; but even then it is not perfect unless confined. Now, at present, no dynamite containing more than 75 per cent. of nitroglycerin is permitted in this country, and as the kieselguhr which is now generally employed has a greater absorbing power, it becomes necessary to reduce it by the addition of less absorbing materials, such as barytes, mica, talc, or ocher, in substitution for an equal amount by weight of kieselguhr.

Dynamite, as above described, is a soft plastic material, possessing a specific gravity of 1·4, varying in color from light yellow to yellowish red. It retains completely the properties of nitroglycerin, while its tendency to explode, by slight concussions or blows, is diminished. It can be exploded under ordinary conditions by a detonator containing five grains of fulminate of mercury, or by heating to a temperature of 400° F., or by a sharp blow. When ignited by means of a fuse or match, it usually burns slowly away without exploding. When exposed for a short time to a temperature below 40° F. the nitroglycerin in the dynamite freezes and it becomes a hard solid mass. In this condition its sensitiveness to concussion is greatly diminished; but it is more liable to explode on simple ignition. Even a rifle bullet fired through it at a comparatively short distance fails to expode it, whereas a similar treatment would cause the detonation of the unfrozen material. The fact of dynamite freezing so readily is a fruitful source of accidents, occasioned more often by the reckless treatment it is subjected to with a view to restoring to it its plastic properties. Instances are on record of workmen placing frozen cartridges on the top of a fire or holding them on a shovel over a forge fire. Even when slowly thawed at a moderately increased temperature the greatest caution should be exercised in handling such cartridges. In actual contact with water for any length of time the nitroglycerin has a tendency to separate out, and it should therefore never be placed in wet blast holes unless properly protected. Accidents have occurred through neglect of such precautions, the nitroglycerin having percolated through crevices in the rock some distance from the seat of the charge.

Blasting gelatin is the characteristic type of class 3, and consists of—

Soluble guncotton, 7 per cent. to 8 per cent.
Nitroglycerin, 93 per cent. to 92 per cent.

It is prepared by adding a soluble guncotton to nitroglycerin. The latter dissolves the former and is converted into a pale yellow elastic, gelatinous, semi-transparent mass. When ignited by a match it burns slowly with a yellow flame. When heated to 90°-95° F. it should not materially soften nor become moist or show any sign of exudation. At a temperature of 400° F. it explodes violently. Under ordinary conditions it is far less sensitive to concussion of blows than either of the ingredients of which it is composed. Its two constituents, each in themselves sensitive to ordinary means of detonation, become comparatively inert when united, owing to a change in their physical condition. When unconfined, a detonator containing 1 grm. of fulminate is insufficient to explode it. If, however, it be strongly confined so that the fulminate exerts its whole force, it explodes with a violence greater than that of nitroglycerin.

Blasting gelatin, like ordinary dynamite, freezes at 40° F. to a hard solid mass, and in this state, unlike dynamite, becomes more sensitive to concussion. A quantity of fulminate of mercury sufficient to detonate ordinary dynamite in the unfrozen condition will fail to detonate unfrozen blasting gelatin. The same quantity of fulminate, however, is sufficient to determine the explosion of frozen blasting gelatin, whereas it would be totally insufficient to explode frozen dynamite. Its behavior is also the reverse of that of dynamite with regard to the impact of a bullet fired from a rifle. After long immersion in water, it becomes of a paler color and opaque; but its explosive properties are unaffected. It is therefore specially adapted for submarine mining.

Two varieties of blasting gelatin have been recently introduced in this country, namely, gelatin dynamite and gelignite. The first, as its name implies, ought to be placed midway between blasting gelatin and dynamite. It consists of a thin blasting gelatin mixed with other substances, such as cotton or wood meal, and contains about 80 per cent. nitroglycerin. The second variety contains the same ingredients as gelatin dynamite mixed with nitrate of potassium or other nitrate, and contains 60 per cent. of nitroglycerin. They are both very similar in appearance to blasting gelatin.

The invention and introduction of the blasting gelatin class of explosives marks a distinct advance in the history of modern high explosives, the importance of which is as yet but partially realized. The question of their stability has retarded their development, but when once removed it would appear that the problem so long confronting manufacturers of explosives would seem to be solved. Concentration of force in small compass, permanency, safety in use, and under ordinary conditions unaffected by immersion in water—all these properties seem to fulfill in high degree the requisites of the ideal high explosive both for civil and military purposes.

Carbo-dynamite, the invention of Messrs. Borland & Reid, comes under the second of the dynamite class. The novel feature of this explosive consists in the use of a carbon, specially prepared, and capable of absorbing about nine times its own weight of nitroglycerin. The carbon employed for absorbing the nitroglycerin takes an active part in the explosion, and increases the energy over and above that which is due to the nitroglycerin contained in it. This arises from the fact that the nitroglycerin contains sufficient oxygen in excess to burn the carbon on detonation, leaving no residue. Two varieties of this explosive are manufactured, namely, No. 1 and No. 2.

Carbo-dynamite No. 1 is a soft plastic material possessing a specific gravity of 1·5. It consists of 90 parts by weight of thoroughly purified nitroglycerin and 10 parts by weight of cork carbon. Like dynamite, it retains completely the properties of nitroglycerin, while the tendency to explode by slight concussion or blows is diminished. Unlike dynamite, however, it is not acted on by water even after long immersion, a property which makes it specially applicable for blasting in wet bore holes. When detonated, it develops an energy about equal to that of blasting gelatin.

The No. 2 variety is very similar in appearance to No. 1, and consists of nitroglycerin, 50 per cent.; nitrate of potassium, 44 per cent.; carbon, 6 per cent. This variety develops an energy on detonation somewhat greater than that of dynamite No. 1.

Roburite, one of the latest additions to the list of explosives actually in use, consists of a mixture of nitrate of ammonium, dinitrobenzene, and chloronitrobenzene. The proportion of the chlorinated product is regulated so that 100 parts of the organic components shall not contain more than 4 per cent. of chlorine. It has a density rather less than that of water. Even when freshly made it requires a more powerful detonator to explode it than dynamite No. 1. When damp or slightly compressed, it explodes with difficulty. It is non-sensitive to ordinary concussion or friction, and in contact with a flame ignites with difficulty. When heated, it decomposes without exploding and burns with a smoky flame. These latter remarks hold good, at least, when small quantities are experimented with. On detonation, when strongly confined, it develops an energy comparable with dynamite No. 1. Although a "high explosive," it exerts on detonation more of a rending effect—similar to gunpowder—than a shattering one. It has been used successfully for blasting coal and for quarrying.

"*Bellite*" and "*securite*" are similar in composition to the above, in so far as their constituents consist of nitro-compounds of the aromatic series incorporated with oxidizing agents, preferably nitrate of ammonium.

Favier's explosive, which has, under the name of "miners' safety explosive," been licensed in this country, consists of nitrate of ammonium and mono-nitro-naphthalene, in proportion of 91·5 of the former to 8·5 of the latter. The cartridges are made in the form of compressed hollow cylinders, inclosed in waterproof wrappers. The central cavity is filled with a powerful explosive, such as dynamite or guncotton.

The few explosives which I have briefly referred to above include all those of any importance which are in actual use for industrial purposes in this country.

The question, "Which is the best explosive?" has often been put to me. It is like asking an engineer which is the best tool for drilling a hole. Every explosive has its special properties, and no hard and fast rules can be laid down as regards the most economical application of explosives generally. A knowledge of the special properties of explosives enables one more or less to say which particular explosive is likely to be the most suitable for a particular class of work. To use a quick and powerful explosive for blasting coal would be as absurd as to use a diamond drill for boring holes through a deal board. The application of explosives to the best advantage is more a matter of judgment based on actual practical experience. Generally speaking, one may say that for hard rock, especially in tunneling, one would choose, on economical grounds, the most powerful class of explosives with a quick shattering action and of the highest possible density. For blasting coal or in quarrying marble or slate, and in all cases where the material operated on is required in large blocks, an explosive possessing a slow-rending action is preferable.

The rapid development of the trade in modern high explosives has taken place under the controlling regulations of an act of Parliament which came into force in 1875. That this act was framed with considerable foresight in the interest of the trade and of public safety has been fully demonstrated by results. An examination of the reports made by Colonel Majendie, her Majesty's chief inspector of explosives, and his colleagues, Colonel Ford and Major Cundill, to the Secretary of State, conveys a clear idea of the rapid growth of the explosives industry since 1875. The uniformly progressive increase in the number of factories and magazines, which naturally brings with it an increased

* Full details of this accident are contained in a report (No. lxxxi., 1887), by Colonel Majendie, C.B., her Majesty's chief inspector of explosives to the Secretary of State.

employment of labor and an increased risk, has been accompanied by a steady decrease in the number of fatal accidents in manufacture and storage. During the years 1868–70 inclusive, when no sort of inspection existed, the annual fatalities amounted to 43 in number. The average fatalities for the four years preceding the act were 37 in number, with 33 factories at work. There are now 112 factories in operation—many of them manufacturing new explosives—yet in 1888 only six fatal accidents are recorded, and of these three occurred in firework factories. The number of accidents recorded in *the use* of explosives do not show a diminishing tendency to the same extent, and for this the nitroglycerin class of explosives is chiefly responsible, but the result is not to be wondered at considering the increasing demand for these explosives. Further, it must be borne in mind that *the use* of explosives is not controlled by the provisions of the act.

The average number of accidents in the use of gunpowder during the last ten years is 28·4, causing 15·6 deaths, and injuries to 33·9 persons. The accidents in the use of dynamite and other nitroglycerin preparations during the last ten years show an average of 18·4, causing 11·0 deaths, and injuring 21·1 persons.

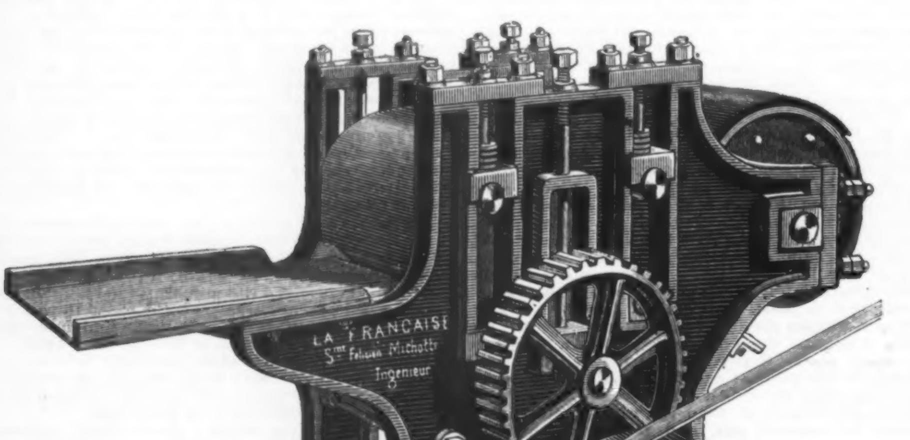
Of dynamite, 1,120,800 pounds were imported into this country in 1888 in 47 cargoes, showing a considerable increase over the quantity imported in 1887, and representing a value of between £50,000 and £60,000, and Dr. Dupre reports that in no instance has he found it necessary to recommend the rejection of this foreign dynamite.

The conveyance of explosives by road is to a great extent controlled by local authorities, and the responsibility of enforcing the law practically rests with them. The transport of explosives on railways is still practically limited to gunpowder. This is much to be regretted.

MACHINE FOR DECORTICATING RAMIE.

THE principal machines of group vi., class 54, at the exposition, are designed for decorticating ramie. One of these, Michotte's, seems to us to have solved the problem of rapid decortication, and, consequently, that of a large production. Unlike the old Favier machine, which decorticates dry material, this decorticates the plant while green. It consists essentially (see figure) of four crushing cylinders of quite large diameter and thirty-one inches in length, provided with grooves of a new form and arrangement. In front of these cylinders there is an endless feed-cloth which carries the stalks to the cylinders, and which is suppressed in the "La Francaise Coloniale" type and replaced with a table. Behind these is an elastic steel scutcher with a counter scutcher of special form. The stalks presented to the crushing cylinders are at once seized and carried along. After being crushed, they reach the counter scutcher, where they undergo the very vigorous action of the scutcher, and are received by a workman who places them alongside of him. This machine is capable not only of decorticating green stalks stripped of their leaves, but also (what has not hitherto been done by any other machine) of treating stalks with the leaves on. The production per hour is 4,400 pounds of green stripped stalks and 8,800 of unstripped ones, giving 6,600 pounds of humid strips, that is to say, effecting the decortication of the product of 2½ acres per day. Of dried stalks, it decorticates 2,200 pounds per hour.

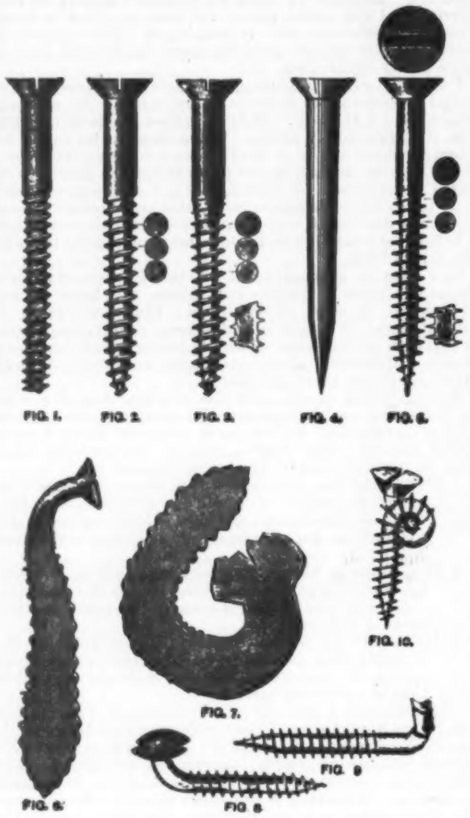
The dimensions of the machine are quite limited (3·6 × 5 feet), and its weight does not exceed 1,980 pounds.—*Le Genie Civil.*



MICHOTTE'S MACHINE FOR DECORTICATING RAMIE.

SCREWS AT THE PARIS EXHIBITION.

ONE of the greatest novelties in the Paris exhibition is to be seen at the stand of the American Screw Company, of Providence, Rhode Island. The company exhibits two machines which produce wood screws, and other similar products, by a new process by which the



metal is caused to flow in the direction required, and the thread and head of the screw are built up from the wire. Nothing is therefore cut away, and all the material is utilized. The process is the result of a series of costly experiments, extending over a long term of years. The process is interesting to the general public on account of its novelty; and it is also interesting to the specialist, since it may be productive of numerous results at present unforeseen. Drop forgings have shown what can be done with hot metal by swaging, but the introduction of a homogeneous metal has rendered possible the manufacture of screws and other products by the cold rolling and swaging process, as developed and applied by this company.

For many years screw threads have been rolled by experimental machinery, but such machinery was only capable of turning out screws having a shallow thread and a short length, and they were not of much use, as the material was too soft for most of the uses to which a screw has to be applied. The present machinery, however, works on the principle of forcing the metal displaced by the dies in a lateral direction, instead of allowing it to move longitudinally as before. In addition to the process for enlarging the diameter of the thread some four to six sizes larger than the body of the blank, and without which the enlarged diameter of the thread would have no practical value, there is the supplementary process for producing a corresponding enlargement of the head, having a swaged slot and a finished surface. Two machines are required for the production of a screw. The first machine takes the wire and holds it firmly in a clamp, while two strokes from a die form the head, and a third stroke produces the slot in the head. The wire is then carried forward, and a pair of shears cut off the required length, leaving a taper point. Fig. 4 shows the screw as it leaves the first machine. These forms are then thrown into a box attached to the second machine, where they are arranged automatically between guides, which keep them vertical and pass them on to the dies. These dies raise the thread and turn out the screws finished at the rate of 60 a minute, whereas the ordinary screw-making machines now in use turn out not more than about seven in a minute.

The illustrations herewith show the forms of the ordinary cut screws, as well as the screws made by this process. Fig. 1 shows a screw made in 1776, before drawn wire was used. Fig. 2 shows the gimlet-pointed screw, patented by J. T. Sloan in 1846. Fig. 3 shows the improvements in the Sloan screw up to 1876. Fig. 4 shows the state of development as the wire leaves the first machine, having the head and point formed. Fig. 5 shows the finished screw, made by the swaging and rolling process. The accompanying Figs. 6, 7, 8, 9, and 10 show screws made by this process, which have been hammered, bent, and twisted in every direction, not one of which has broken.

The following statement shows the machines necessary for the production of 5,000 gross of wood screws in ten hours:

	Fr.
1. By the cutting process—	
14 Machines to form the head, at 3,500fr.	49,000
125 Machines to turn and form the slot, at 1,500fr.	185,000
250 Machines to form the screw thread, at 1,250.	312,500
	546,500
2. By the swaging and rolling process—	
30 Machines to form the head, at 5,000fr.	150,000
38 Machines to form the screw thread, at 1,600fr.	60,800
	210,800

Difference, 335,700fr., or 61 per cent.

	Lb.
Number of pounds of material required to make—	
5,000 gross by cutting method of steel wire.	10,000
5,000 gross by method of swaging and stamping	6,000
	4,000

Or a difference of 40 per cent.

	Fr.
Values of the screws produced by the two methods—	
The process of swaging and rolling gives with No. 9 wire 5,000 gross of screws, 1½ in. long, No. 13 wire gauge	70,711·20
The old process of cutting gives with No. 9 wire 5,000 gross of screws, 1½ in. long, No. 9 wire gauge	44,402·40
	26,308·80

Or a difference of 59 per cent.

—*Industries.*

ESPARTO.

SINCE the late Mr. Thomas Routledge introduced esparto to paper makers as a pulp-yielding material, its consumption in the paper industry has been very great. There is perhaps no other fibrous plant which has in modern times received such an amount of favor among paper makers. The present mill-working generation having been reared in close association with this fiber, they are apt to consider it superior to any other. Its excellence as a paper-making material is undoubted, as it yields a soft, pliable, moderately long fiber of good felting properties, and which is easily bleached to a very staple color and capable of being manipulated with ease in the beater engine. When the pulp from it is properly prepared, it produces a paper whose qualities nearly approach those made from worn cotton rags. Indeed, esparto grass, if not altogether, certainly in a very large measure, has taken the place of rags in the production of certain classes of paper.

From a practical point of view, it is probably the only known fibrous-yielding plant which, on account of its cost, is capable of being used, whose fibers so closely resemble the pulp manufactured from worn cotton rags in physical properties, and it would probably be difficult to find any other substitute for it among the many fibrous plants so often brought before the notice of paper makers, and whose merits are frequently so ably and so powerfully expounded.

The characteristic feature of esparto paper is great softness to the touch, and on this account it produces a paper very suitable for type-printing purposes, in which the protection of the faces of the type is so important. For this reason it enters very largely into the composition of printing papers of every grade, and if they are not wholly composed of esparto pulp, they usually contain a very appreciable percentage of it. It is blended with coarser and harder fibers to communicate a certain degree of softness and pliability to papers which otherwise would be hard and crisp. Certain kinds of writing papers also contain it in varying quantities.

The amount of esparto grass annually imported into this country, all of which is consumed in the paper industry, is about a quarter of a million tons, the greater part being obtained from Algeria, Tunis, and Tripoli, in North Africa, and the remainder from Spain and other countries. Of the total amount shipped from these countries, England receives the greater propor-

tion, no very large quantity having as yet been worked in America or in other European countries excepting our own.

The German paper makers hardly know the fiber at all, and it may be said that it does not enter into the composition of their papers. It is, moreover, not at all likely that it will ever be largely imported and used in those countries where wood is cheap and prevalent, for of all the fibrous-yielding materials suitable in every respect for paper making, wood is the most powerful opponent of esparto, more especially when we remember that the different varieties of timber produce distinct but almost every required quality of pulp as regards softness, pliability, and felting properties, and that the choice of wood is not limited to one variety alone.

The difference in the esparto from the above places are distinct and well marked, and those differences are fully appreciated by paper makers. Thus, a fully matured grass, one that appears bright and having an almost entire absence of chlorophyl (the green coloring matter of plants), is the most easily worked. It is nevertheless difficult to venture an opinion as to the relative values as regards the pulp-yielding qualities of different espartos, even after prolonged experience in preparing the fiber on the large scale from different kinds of grass for the purposes of paper making, and also from careful investigation in the laboratory.

We hesitate still more when we consider this important subject from the standpoint of the cost of working or of producing a ton of air-dried pulp. The grasses from different countries, and, indeed, from the same locality, often present diverse appearances and physical properties, and as neither chemical analyses nor chemical investigation has yet been fully recognized as an aid to the manufacturer in purchasing or in selecting any particular kind or lot of esparto, the quality thereof is often simply a matter of observation, and his conclusion as to the probable yield of pulp from it more a matter of conjecture than of fact.

We do not wish to infer that the present mode of purchasing esparto is altogether unsatisfactory, for we are well aware that the various shipments of the grass from the same locality are fairly consistent in quality, but we wish merely to point out that, as there is not a great difference between the yield of pulp from the finest and lowest qualities of the grass, and as there is a great difference (33 per cent.) in their original cost, it is still a matter for consideration whether or not the coarse varieties cannot be made to produce a much cheaper pulp and quite as satisfactory a paper as the finest grass.

The fine qualities of the grass, such as Spanish esparto, are cleaner than the coarse, low qualities, producing with a small amount of labor for cleaning a pulp, comparatively speaking, free from "sheave." And yet when we compare samples of paper made from the best Spanish esparto with others made from a low quality of grass, we are somewhat disappointed with the margin of difference in their appearance, and are driven almost to the conclusion that the coarse, low qualities, if properly manipulated in the paper mill, will produce papers as clean and as soft as the finer sorts.

We are well aware that the labor and chemicals, etc., expended upon the production of one ton of pulp (or of paper) from low quality esparto is greater and therefore more costly than for the finest grass. It is, nevertheless, still doubtful to many whether or not such increased expenditure is greater or less than the difference between the purchasing value of the quantities of esparto used and which are compared. It may cost more to manufacture a ton of pulp from Tripoli (fair average), but the excess of this cost over that for an equivalent quantity of pulp from Spanish grass may not compensate for the difference in value between the respective quantities of the two espartos.

Is the difference in the cost of a ton of pulp from Tripoli and Spanish esparto at all in proportion to the difference in the appearance and strength of the respective papers made from these two varieties? and is a proportionately higher price obtained for the paper made from Spanish than from Tripoli?

The requirements of good Spanish esparto are that the blades of grass be of average fineness and length, be fully matured and free from roots, which, if not removed, produce more or less sheave in the finished paper. On the other hand, Tripoli (fair average), which may be taken as representing the lowest quality of esparto, is of a coarse nature, the blades of grass are of greater diameter, longer, stronger, and stiffer, appear less matured, and consequently of a greenish color. It contains, moreover, more roots and weeds than the fine varieties.

The amount of mineral matter or ash is about the same in both fine and coarse qualities. The amount of water which espartos contain is of greater importance than the mineral matter, because it varies and controls to a certain extent the percentage yield of pulp. Any increase in the percentage of water, over that usually present, increases in direct proportion the amount of grass required per ton of pulp or paper made.

Many chemists have from time to time analyzed esparto to arrive at a knowledge of its exact composition, and have published their analyses. To perform this analysis is a difficult task, requiring great skill, but we quote the results obtained by Muller, who certainly has the advantage of vast experience in this department of analytical chemistry.

Composition of espartos, according to Muller:

	Spanish.		African.	
Cellulose..	48·25 p. c.		45·80 p. c.	
Fat and wax.......	2·07	org.	2·62	org.
Aqueous extract. ..	10·19	matter	9·81	matter.
Pectous substances	26·39	38·65	29·30	41·73
Water.........	9·38		8·80	
Ash	3·72		3·67	
	100·00		100·00	
Cellulose on absolutely dry esparto..............	53·23		50·21	

We have calculated from these analyses the respective amounts of cellulose on 100 parts of absolutely dry esparto, from which it appears that Spanish always contains a greater percentage of fiber than the other when the respective amounts of water are the same in each. From a manufacturer's point of view, however, such a comparison is of little value, because in actual work we have to deal with the composition of the esparto as delivered or as purchased. The Spanish contains 2·45 per cent. only more cellulose than the African, while the latter contains 3·10 per cent. more extractable organic matter—other than pure fiber—than the former, a fact which doubtless indicates that the variety of African grass analyzed was less matured than the Spanish. The amount of ash in each is practically the same.

We are well aware that, as a general rule, paper makers are not chemists, but we know of many engaged in this important industry who are at all times willing to listen to the teachings of chemical science and chemical investigation, and, also, are ever willing to follow the paths into which these investigations generally lead. To others of another turn of mind, these analyses may appear to be of no practical value. If they do not teach the practical mill manager something of the nature of the material he has to manipulate, they do, at least, point out very clearly and definitely the greatest amount of fiber he can possibly obtain from unit weight of esparto. This is the most important function of chemical analysis, and is of vast importance to the manufacturer. By the aid of such analysis he can to a large extent govern his losses and gains.

The yield of fiber available for paper-making purposes is always an important matter. The fiber in a ton of paper costs more than all the other ingredients put together and frequently the additional cost of converting the pulp into paper. Hence, it is important always to aim at obtaining the maximum yield of pulp with minimum consumption of material consistent with the quality of product required for the special class of paper to be made.

We would recall to the minds of those engaged in this and the paper pulp industry, that the practical yield of pulp in very many cases decides the magnitude of the profit in the year's working, and has at any rate a remarkable influence upon it.

It is difficult to make definite statements as to the amount of available pulp, that is, pulp actually obtained for conversion into paper from one ton of esparto, for, as above recorded, the yield greatly depends upon the chemical composition of the esparto treated. In this case the ingredients which influence the percentage yield of pulp are mainly the amount of water contained in the esparto, and also the cleanliness of the grass, both of which, if they exist in large quantity, are tantamount to a considerable decrease in the yield. Paper manufacturers, as a rule, only use one or two different kinds of grass nearly equal to one another in quality, and seldom (or perhaps never) are such widely different varieties as the finest Spanish and coarse Tripoli (fair average) blended in the production of any paper. If the particular grass used contains say 2½ per cent. more moisture than usual, its influence reckoned on the basis of one ton of pulp is not merely measured by an increase of 2½ per cent. in the weight of esparto needed, but substantially by 2½ per cent. on the net cost of producing the ton of pulp.

We have endeavored to show the necessary chemical and physical conditions that should be observed when cooking esparto, and have, as far as we thought suitable and necessary for our purpose, given general data with respect to what will take place if any of these conditions be neglected or overlooked. While it has been our concern thus to point out the influences which control such an operation, the fact may be that many manufacturers have not hitherto looked upon the subject of yield of fiber strictly from our standpoint, and consequently that the causes of low yield have not been known, or if known have been dismissed from consideration solely on the score of thoughtlessness. It may probably be asked by many paper makers to what extent do these figures relate to his individual case; and, is it at all probable that any one in this industry is losing fiber owing to the non-observance of such conditions?

We venture to think that in many cases this is so. Unfortunately, every manufacturer is not in a position to obtain figures relating to the exact mode in which their individual work is carried on in the digesting house, chiefly for the want of properly skilled labor, and it is a matter of surprise that paper makers are not more alive to the fact that chemists are of immense value to them. When we say chemists, we do not mean those who are alone capable of performing chemical analysis, but who are, strictly speaking, chemical technologists—men capable of analyzing an engineering problem with as great a certainty and ease as one of simple chemistry.

We have, however, dealt mainly with the chemical aspect of this subject, and we purpose returning to the principal features of what may be termed the mechanical or physical conditions involved in the treatment of esparto at some other time. At present we would again point out that which must be apparent to those of our readers who have followed us so far, that to obtain economically the maximum yield of pulp from unit weight of any variety of esparto does not depend altogether upon the proper regulation or fulfillment of any one to the exclusion of the others of the working conditions which we have enumerated, namely, as to (1) the quantity and strength of the caustic soda lye employed, or (2) the temperature or pressure at which the digesting operation is carried out, or (3) the time required to complete the process, but upon the proper adjustment of all three; and he who can adjust these in such a manner as to obtain as nearly as possible the theoretical yield of fiber, or that obtained by calculation from the analysis of the esparto treated, may be justly recognized as having accomplished practical perfection. As a matter of fact, however, most mill managers must grope somewhat in the dark in their attempt to get high results, for, as previously mentioned, they do not know what their yield is, and necessarily must employ the chemist to aid them in ascertaining it. It is, doubtless, perfectly true that one manufacturer may obtain a higher yield than another, though they work with the same esparto and such difference may be due, not to small differences in the composition of the esparto, but to the carelessness with which the manufacture is carried out and to the peculiarities of the plant he works—in its construction and arrangement or in other conditions, which may prevail in one mill and be absent in another, such peculiarities causing a slight alteration in the conditions, and, of course, having an effect on the practical issue. Thus it is that esparto boilers, when charged with perfectly cold materials (lye and grass) require more steam to heat up the contents to the required temperature, and therefore there is a greater condensation of steam within the boiler, which dilutes the lye, and of course alters its strength. And it must not be imagined that this has no influence upon the resulting pulp. In such cases, the proper regulation of the strength of the lye pumped into the boiler must be observed, and an allowance made to meet the exact requirements of the case. We merely mention this as an example of what might take place under different physical states of the plants and materials.

As the cost of recovering the soda from the spent lyes, and also the cost of the caustic alkalies used to replace that loss which always goes on, more or less, in manufacturing operations, have been greatly reduced during the past few years, it requires some degree of consideration and of calculation in order to decide whether or not it is cheaper in any works to decrease the amount of caustic soda used, and to prolong the time of digesting, and raise the pressure above that usually employed, rather than use a reasonable excess of caustic, and shorten the time of boiling, and lower the pressure, particularly in the case of Oran and Tripoli grass. As a general rule, the cost of the caustic soda lye is more than the fuel and other items, and as most manufacturers have sufficient boiler space (capacity) for their requirements, the latter in many cases need not enter into consideration. To produce a ton of air-dried pulp from Spanish esparto, somewhere about 5¼ cwt. of 60 per cent. caustic soda are used, while for Tripoli from 9½ to 10 cwt. are generally used. Such being the case, it is apparent that it is more advantageous to reduce the quantity of soda in the latter instance than reduce either the steam pressure or time of digesting, and keep the caustic up to 10 cwt.

From Spanish esparto a greater percentage yield of pulp is obtained in practical work relatively speaking to the theoretical amount contained in the original grass than is the case with Tripoli, for reasons which we have already explained, but there is no reason why when working with Tripoli the same relative yield may not be obtained as in the case of the Spanish. The difference between them is no doubt due simply to the different manner of manipulation. We might illustrate what we mean more clearly by stating that Spanish esparto, containing say 50 per cent. pure fiber according to analysis, will yield, after boiling for four hours in caustic lye of suitable strength, and the quantity of which does not exceed 13·5 lb. of 60 per cent. caustic soda per cwt. of grass, at a temperature of 298° Fah. (equal to 50 lb. pressure), the percentage yield of pulp washed free from alkali, unbleached and unbroken, will amount to about 3 per cent. less, namely, to 47 per cent., that is on 100 parts of the original esparto. On the other hand, the difference in the yield of fiber from Tripoli esparto, between the theoretically possible amount (obtained by calculation from the analysis) and that obtained in practice, by boiling for four hours at 50 lb. pressure with 20 lb. 60 per cent. caustic soda per cwt. of grass, is greater than 3 per cent. and oftentimes very considerably greater. The coarse Tripoli grass seems to be subjected to a more severe action because of the larger amount of caustic soda liquor usually employed, and by modifying the quantity of this reagent and probably prolonging the time of digesting, and also increasing the steam pressure or temperature, or, indeed, by altering either of the two latter conditions, a more favorable yield of pulp would be obtained.

We do not hesitate to believe that not much more than 35 parts of fiber available for conversion into paper are obtained in actual practice from 100 parts of Tripoli (fair average), and in some instances we believe it to be very much lower than this. This is from an esparto which gave by chemical analysis from 42 to 43 per cent. fiber. The practical yield must of course vary with the circumstances of each mill. Spanish esparto gives much more; if it is well matured and otherwise excellent in quality, as high as 44 per cent. or even more of pulp is obtained for actual conversion into paper. In the absence, however, of exact figures obtained in manufacturing practice there will doubtless always be a difference of opinion on this subject. It may not, however, be out of place for any one to ask the question to what extent does any increase in the yield affect the cost of esparto pulp, and we shall endeavor to state several items that we consider are adequate answers to the question. It is quite plain that—

(I.) The amount of caustic soda lye used per unit of pulp produced is lessened, and consequently less soda required to be recovered. Whatever, therefore, is the cost of recovering the soda from the spent liquor and repreparation of the caustic lye under the old order of things, any less soda used affects the cost of the alkali in the same proportion and in the same direction. That is to say, if, instead of using

16·5 lb. of 60 per cent. caustic soda per cwt. of Oran, we use 14·5 lb.,

and instead of

20·0 lb. of 60 per cent. caustic soda per cwt. of Tripoli, we use 15·5 lb.,

which quantities bear nearly the same proportion to the extractable organic matters in these espartos as 13·5 lb. of 60 per cent. caustic soda does to the organic matter in Spanish, the amount of soda which has to be recovered, assuming an equal percentage recovery for each, is lessened in the first instance (Oran grass) by 12 per cent. (nearly), and in the second by 22·5 per cent. There is therefore a saving in cost of alkali to all intents and purposes to this extent. Indeed, it is so appreciable that it is bound to make itself felt in the cost of manufacturing the pulp.

(II.) By reducing the soda a greater yield of pulp is obtained from unit weight of esparto, and assuming that the increased yield is only 5 per cent., calculated on the pulp produced, it is equal to an increase in actual fiber of 1 cwt., or, instead of obtaining 20 cwt. of pulp from a certain quantity, whatever that quantity may be, 21 cwt. of pulp are now obtained. Esparto pulp costs, we should say, at the very least 13s. per cwt. air-dried weight, and whatever the increased yield is, the saving in intrinsic money value can of course be easily reckoned.

Although there are real savings, it might be argued that should the caustic be reduced, and the time of

boiling prolonged, the amount of fuel required to complete the digesting process shall be greater, and we admit this to be the case. But in well regulated mills the extra amount of fuel required to maintain, the digesting operation for an additional two or three hours beyond the time ordinarily required is small compared with that required to commence the process, and continue it for the first hour or so. The extra quantity of coal will hardly be noticeable in actual fact, and in no instance, we venture to believe, will it seriously interfere with the consumption of the steam, or in the generation of the steam in the steam boilers. Of course, there are circumstances of which we can conceive under which a prolongation of time occupied for digesting would interfere with the ordinary routine work of any mill, but these are so extreme that it may be accepted that they seldom exist in general practice, and are absent in all well regulated factories.

Then, again, the necessity of requiring more plant or boiler space may be urged as another reason why this course should not be adopted, and it is quite true that the boiler capacity would require to be augmented should it only be sufficient for the requirements of the mills under any less economical system of working. The manufacturer himself is the only one to decide any such question where increasing the plant is concerned. The time of digesting might be kept the same as before, and the pressure raised, in which case the boiler capacity does not enter into the question, while the fuel is, of course, increased.

Most likely those practical paper makers who have followed us thus far have come to the conclusion that the question of percentage yield of fiber from esparto is to them a very important one, that, indeed, any increment in it favorably affects the cost of producing the pulp. They are, nevertheless, so bound to conform to certain matters relating to quality in the manufacture of their papers that it may seem to them very difficult to make alterations in their methods of working, and endeavor to realize any improvement in their particular case of manipulating esparto by acting upon the suggestions contained in this article. We do not anticipate from such any expectation that they will succeed in obtaining better results. But to those who know their methods to be somewhat crude, our aim has been served if we have made clear to them the principles which underlie the subject matter of this paper. We know well the advantage of possessing the power of chemical investigation and engineering practice in manipulating esparto, and probably there is no branch of manufacturing industry where greater skill and attention is required than in the boiling house of a paper mill when high-class results are wanted.—*Chemical Trade Journal.*

ON M. H. HERTZ'S EXPERIMENTS.*

By M. JOUBERT.

DR. HERTZ, professor at Carlsruhe, published in the course of the year 1888–89 some experiments of very great interest. I have repeated the greater number of them, with the assistance of M. De Nerville, at the Central Laboratory of Electricity in the Place Saint Charles. The large hall at the laboratory, which forms a rectangle of 15 meters by 14 meters, enabled me to reproduce them under very favorable conditions.†

The great interest of M. Hertz's experiments lies in the accurate information that we gain from them concerning the intervention of the external medium in electrical phenomena. The idea of this intervention is not new. After Faraday's experiments and Maxwell's theories, there remained no doubts upon this point in the minds of physicists; but the experimental proof was wanting, and this proof has now been given to us by M. Hertz's experiments. They show, in particular, that the medium which intervenes in electrical phenomena is the same ether that forms the seat of luminous phenomena; that the disturbances in both kinds are set up under the same conditions, and with the same rapidity; and lastly, that there is identity of nature between certain electrical phenomena and the luminous phenomena.

What is an electrical current? We do not know: but the following hypothesis gives us a very good idea of what occurs. Let us consider a conducting wire, in its natural condition, as connected to indefinite elastic cords, normal at its surface. To introduce a current into the wire is to displace the wire in a direction parallel to itself and with the nature of the current, so as to draw with it the points of attachment of all the cords. These latter become oblique and remain oblique while the current is passing, but return to their orignal position and resume their normal direction as soon as it ceases. These cords being indefinite, the effect of the current makes itself felt at any distance, but evidently less and less, in proportion as the distance is increased.

But it is also very evident that the effect is not felt everywhere at the same moment; it arrives progressively at the various points, and takes rather more than eight minutes to arrive at the sun. We may add that what is called the *coefficient of self-induction* is only the coefficient of the term that corresponds to this external work of the creation of the field.

It should be well understood that the phenomenon of which I have just spoken has not its analogy in luminous phenomena. In order to produce the resemblance, we must consider alternating currents. Let us introduce into our rectilineal conductor an alternating current of a sinusoidal form; the elastic cords will be drawn alternately into first one direction and then the other, and each one will be the seat of transverse vibrations propagated along its length. We will, according to custom, call length of undulation the path taken by the movement during a complete vibration backward and forward.

It is under the action of these movements, transmitted through ether, that a conducting wire, stretched parallel to the first, becomes the seat of induction currents. We may remark that if this wire is stretched at a distance from the first equal to the length of undulation, it will give, at about the same intensity, the same phenomena of induction as if it were in contact; but that if it were placed at half this distance, *i. e.*, at a distance equal to a half length of undulation, the induced movements would be at each moment of a nature contrary to those produced in a wire adjoining the conducting wire, the only ones that we are accustomed to consider, and that the elementary laws of direct and inverse currents would be reversed.

The experimental verification of this fact would be the most direct proof of the propagation of the electric action; but if the rate of propagation is the same as that of light, viz., 300,000 kilometers per second, and if the period of our alternating current be $\frac{1}{100}$ of a second, the wave length will be 3,000 kilometers, and the distance of the two wires would be 1,500 kilometers.

In order to get a wave length of 3 meters, the duration of the vibration must not exceed $\frac{1}{100000000}$ of a second.

We cannot hope to produce directly alternating currents of such a short period; but we know that under certain conditions of resistance of the circuit the discharge of the Leyden jar is effected by isochronous vibrations of very short duration; but these oscillations have always been found to range from $\frac{1}{10000}$ to $\frac{1}{100000}$ of a second. It is the same with the oscillation produced in the open circuit of the secondary wire of a Ruhmkorff coil at each interruption of the inducing current. This minimum duration of $\frac{1}{100000}$ of a second corresponds to a wave length of 3 kilometers.

One of M. Hertz's great achievements is to have found a method by which still more rapid oscillations can be given, the duration of which may be reckoned in billionths of a second. Theory points out that if two spheres (Fig. 1) charged with different potentials

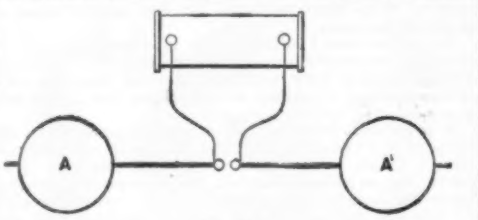


FIG. 1.

are put in communication by a conductor, equilibrium is established by a series of isochronous oscillations, rapidly checked, like those of a liquid contained in communicating tubes, the level of which has been disturbed. The duration of the oscillation depends on the capacity, C, and the coefficient of self-induction, L, of the system, and is given, when the resistance of the joining wire may be disregarded, by the formula

$$T = 2\pi\sqrt{LC}$$

Such is briefly M. Hertz's apparatus, which we will call the exciter; it consists essentially of a rectilineal conductor cut in the middle and terminated at its extremities by two capacities, two large spheres or two plates.

In the apparatus placed before the society the rectilineal conductor has a diameter of 0·5 centimeter and a length of 40 centimeters; the two spheres are 30 centimeters in diameter. Consequently we get

$$C = \frac{15}{9 \cdot 10^{11}}$$

$$L = 400$$

$$T = 16 \cdot 10^{-9}$$

From this we deduce for the length of undulation, the speed being supposed to be that of light,

$$\lambda = 4 \cdot 80 \text{ meters.}$$

In order to realize the instantaneous charging of the exciter we leave an interruption in the middle, terminating the two opposite extremities by little balls and putting each of these balls into permanent communication with the two poles of a Ruhmkorff coil. The bobbin employed with the exciter in question is a Carpentier bobbin (type 600 fr.) working with a Marcel-Deprez interrupter and a current which is 15 amperes when the interruption is suppressed.

This is the action of the apparatus. At the moment when induction is produced on the secondary wire of the coil, the two branches of the exciter which form the extremities are brought to different potentials, and at the same instant a bright spark flashes between the two balls, establishing during a very short period between these two balls a passage of low resistance, across which the rectilineal conductor discharges upon itself independently, almost as if it were separated from the bobbin. These oscillations are stopped before the following oscillation of the bobbin, which does not return until after $\frac{1}{10000}$ of a second has had time to take place, and they are renewed in the same manner at each oscillation of the bobbin. The condition of the exciter may be compared to that of a violin string, the vibrations of which are kept up by the sharp drawing of the bow.

The essential condition of the phenomenon is, therefore, that the spark should pass and should be of the intensity required. If we separate the balls so as to suppress it and to leave open the secondary wire of the bobbin, we no longer get the proper oscillations of the bobbin, which are about 10,000 times slower than the proper oscillations of the exciter.

The production of rapid oscillations depends on complex and even somewhat mysterious conditions; they are influenced not only by the distance of the two balls, but also by the condition of the surface, the degree of polish of these balls, the dimensions of the bobbin, the intensity of the inducing current, etc.; a pretty strong violet light falling upon the balls completely puts a stop to the oscillations.

We know whether the apparatus is working well by the report and aspect of the spark; this spark is formed of very fine and very bright rectilinear strokes, giving rise to sharp crepitations.

The exciter naturally develops in the neighboring conductors alternating induced currents. I established experimentally, in 1880 (Comptes Rendus de l'Academie des Sciences, vol. xci., pp. 408 and 493, 1880), the laws of alternating currents. I showed, in particular, that the circuit seemed to have, instead of its resistance, R (the *true resistance*), an *apparent resistance* equal to

$$\sqrt{R^2 + \frac{4\pi^2 L^2}{T^2}}$$

In actual experiments, in consequence of the excessive smallness of T, the second term of the radical takes an enormous value, before which the proper resistance of the conductor may absolutely be disregarded. And thence arise several necessary consequences which impart to the phenomenon quite a special character.

In the first place, the resistance of the conductor is of no importance; all else being equal, the phenomena produced in a wire will be independent of the nature and thickness of the wire. In the second place, there will be established between two neighboring points of the same conductor, which are separated by an apparent resistance which may be enormous, differences of potential out of all proportion to those that we generally observe. Lastly, that property of variable currents of penetrating only progressively the thick layers of the conductor will be carried to its extreme, and the electrical movements will be solely superficial.

In fact, when the apparatus is working well, as at present, and the oscillations are produced, there is not in the room or in the adjoining apartments any piece of metal, large or small, insulated or in communication with the earth, from which we cannot draw sparks. We see them flash between the two extremities of a wire which we curve into a bow, between two pieces of money or two keys that we bring together; we obtain them, by presenting the point of a knife, from the gas pipes, water pipes, etc.

In order to analyze this phenomenon, M. Hertz uses a wire bent into a ring, the extremities of which can be brought together at will. We observe the sparks which pass between the extremities of the wire, and we judge of the intensity of the phenomenon by the explosive distance and by the brilliancy of the spark. On trying rings with different diameters, we find one with which the sparks take their maximum length; it is then that the period of the electrical movement excited in the wire which constitutes the ring is the same as that of the exciter; the ring acts as resonator. And, in fact, if we take a frame of the same diameter, but in which the wire makes several turns, we obtain much feebler sparks.

With a resonator well in accord, the sparks are from 8 to 10 millimeters in the neighborhood of the exciter; they decrease rapidly when the distance increases, but they are still visible at 15 or 20 meters from the apparatus.

I hoped to render these phenomena visible to an audience by employing a frog, but the frog gives absolutely nothing.

Instead of M. Hertz's ring, M. De Nerville and I have employed a rectilinear resonator composed of rods, formed of two copper wires, placed end to end, the extremities of which bear capacities consisting of sheets of tin (Fig. 2).

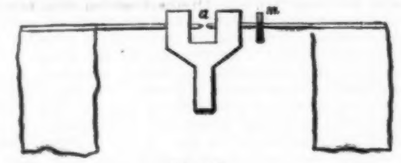


FIG. 2.

We determine by trial the length of the wires and size of the sheets of tin most suited to our purpose. At the interruption, *a*, one of the wires is rounded, and the other cut to a point. The system constitutes a species of micrometer; one of the wires bears a screw thread, and the explosive distance is made to vary by turning the milled head, *m*.

The spark flashes in the space between the two wires. When the exciter is working in the large hall of the laboratory, and the length of the wires and the size of the capacities are well regulated, we observe very brilliant sparks, which attain to 7 or 8 millimeters in the neighborhood of the exciter, and which are visible in all the other halls, in the yard, in the street, and even at a distance of more than 50 meters and through several walls.

This apparatus leads us to a very curious experiment, showing plainly the influence of light on the production of the oscillations. On bringing the resonator near to the exciter, we see that the character of the spark of the exciter changes, and at the same time the spark of the resonator disappears. On interposing any screen whatever, the phenomenon reappears in all its brilliancy. A sheet of glass has the same effect as an opaque screen; but, on the contrary, the interposition of a thin sheet of quartz, which allows a violet light to pass through, does not re-establish the phenomenon. The spark of the rectilinear resonator is at its maximum when the resonator is parallel to the exciter. The spark is *nil* when the resonator is in the symmetrical plane of the exciter, but when turned a few degrees, we see the spark reappear.

A stone wall acts in the same way as a transparent plate as regards the undulations, and we can hardly note any difference between the sparks obtained on the different sides of the wall. A metallic plate acts like a glass very slightly silvered; it reflects part of the wave, but lets a very considerable part pass through; thus the sparks are still very appreciable behind a metallic surface formed of a sheet of tin or a plate of zinc of 0·5 millimeter, or even of a plate of iron of 3 millimeters. These figures are simply the thicknesses of the plates tried, and they have no other meaning. It is probable that we should obtain a more complete reflection with plates of greater thickness or greater conductivity.

I come now to one of M. Hertz's fundamental experiments, that which demonstrates in an undeniable manner the existence of the waves in question. It is an experiment exactly analogous to that by which Savart showed the interference of direct sound waves with waves reflected by a wall. The bottom of the hall was covered with plates of zinc, forming a metallic

* Bulletin de la Societe Internationale des Electriciens, July, 1889.—*Electrical Review.*

† The materials necessary for these experiments were very kindly supplied to us by Messrs. Carpentier and Lemonnier, and by the company for working metals by electricity. I take this opportunity of thanking them for their generous assistance. I must also express my sincere thanks to the young engineers at the laboratory, Messrs. Marganie, Dierman, and Bary, for the help they rendered us throughout.

surface of 4 meters by 6 meters, and the exciter was placed opposite to it at the other extremity.

The vibratory movements provoked by the exciter are reflected upon the metallic surface. By well known mechanism, the reflected waves, interfering with the direct ones, give rise to stationary waves separated by fixed nodes. And, in fact, if we place the resonator very near the wall, we only see faint sparks; they increase when it is drawn away, attain a maximum, then go on decreasing, and finally disappear at a distance of about 2·4 meters, to reappear again. Thus, there is a first node in contact with the wall, as is the case with sound waves when the reflection takes place with change of sign, and a second at a distance of 2·4 meters. The distance corresponds to half a wave length. If we take in the duration of the vibration as calculated above, *i. e.*, 16 billionths of a second, we deduce from it that the rate of propagation is 300,000 kilometers, *i. e.*, that of light.

Thus the vibratory electrical movements, and the vibratory luminous movements, are propagated with the same rapidity. They answer, then, to a modification of the same nature of the same medium. The only difference is in the duration of the period. We can easily obtain electrical vibrations of a billionth of a second, and consequently wave lengths of 30 centimeters. The length of undulation of the visible rays is on an average 0·00005 centimeter; that is, 600,000 times shorter. M. Hertz carried still further the analogy between the two phenomena, and we have repeated the greater number of his experiments. Unfortunately, they are too delicate to be shown in public, and I can only invite the members of the society to come and see them at the laboratory in the Place Saint Charles.* I will now merely indicate the principle of them. An exciter with a very short period is placed according to the focal line of a parabolic cylinder, having a height of 2 meters, with an opening of 1·20 meters.†

The area in which the phenomenon is appreciable, and in which sparks can be obtained with the resonator, is limited by two vertical planes passing through the edges of the mirrors and parallel to the axis of the parabola of the base. We get thus a true parallel electric ray, similar to the luminous ray that would be given by a source of light placed in the position of the exciter. By receiving this ray upon a second mirror, similar to the first, we may repeat the well-known experiment of the two conjugate mirrors, and show that the vibratory movement is concentrated upon the focal line of the second mirror. We may also reflect this ray upon a plane, and show that the angle of incidence is equal to the angle of reflection. We may also make it pass through a prism, show that it deviates toward the base of the prism, and from the deviation deduce the index of refraction of the substance for the electric ray. M. Hertz made this last experiment with a prism of asphalt. This is the only one that we have not been able to repeat, for want of a prism of sufficient dimensions.

The president warmly thanked M. Joubert, and congratulated him upon the charm which he had imparted to his communication upon a subject of the highest scientific interest. He adds that the members of the society ought to congratulate themselves on the fact that their laboratory has enabled these remarkable experiments to be realized.

* An extra *seance* took place at the Place Saint Charles on Friday, July 12th, for the repetition of these experiments.

† We are indebted for these mirrors to the kindness of M. Lemonnier.

PUBLIC EXPERIMENTS IN ELECTRICITY.

THE first scientist who drew electricity from the narrow domain of the laboratory and of learned societies was Lemonnier, son of a physicist of influence in the city as well as at the court. His father was one of the principal members of the Academy of Sciences at the time of the discovery of the Leyden jar. Young Lemonnier, who was scarcely thirty years of age, became deeply interested in the Dutch scientist's discovery. In order to ascertain whether the shock of the Leyden jar was communicated to great distances, he conceived a project that does him the greatest honor.

In the middle of the 13th century, Saint Louis had called the Chartreux to Paris and installed them in the Hotel Vaurant, which popular superstition claimed to be haunted by demons, and which was located at the beginning of Rue d'Enfer. The cloister was surrounded by an immense close, which the prior put at the young experimenter's disposal.

Lemonnier began by placing around the cloister two parallel wires six feet apart, and the total length of which was two and a half miles. The close embraced the Bullier gardens, the School of Mines, the School of Pharmacy, etc. Directing an operator to hold one end of each wire in his hand, and taking himself one of the ends in one hand, he with the other hand touched the other wire with the ball of a Leyden jar that had been charged in advance. At the moment the contact occurred, Lemonnier felt a smart shock, which also struck the man who was interposed in the circuit.

The astonishment which we were witness of at the time of the discovery of the electric telegraph was but a repetition of the wonder of our ancestors. But Lemonnier did not continue in so good a path. He conceived the idea of making the electric fire cross a certain quantity of water. This second operation took place in the great basin of the Tuileries, which Louis XIV. had established in organizing the garden. The arrangement was the same, a wire being carried around a half circumference. Near one of the extremities Lemonnier placed a cork float traversed by an iron pin, which consequently entered the water. Things being thus arranged, he took the extremity of the chain in his left hand, and in his right held a Leyden jar. At the other side of the basin his assistant grasped the chain with his right hand and plunged his left hand in the water. Seeing that his man was at his post, Lemonnier touched the upper extremity of the pin with the jar, and as soon as the contact occurred, both operators received a shock at the same instant. The electric fire had, therefore, traversed a body of water as long as the towers of Notre Dame are high without being extinguished. It is unnecessary to describe here the exclamations that accompanied this experiment.

The history of the progress of electricity is somewhat that of the rivalry of France and England. The Royal Society of London would have thought itself dishonored had it lain still under the blow of this brilliant demonstration. It was necessary to do better. After mature reflection, Watson, who had just obtained the Copley medal, announced that he would pass electricity through the waters of the Thames. The experiment, which is shown in the engraving, and which needs no description, was repeated several times. It was but a repetition of that of our compatriot.

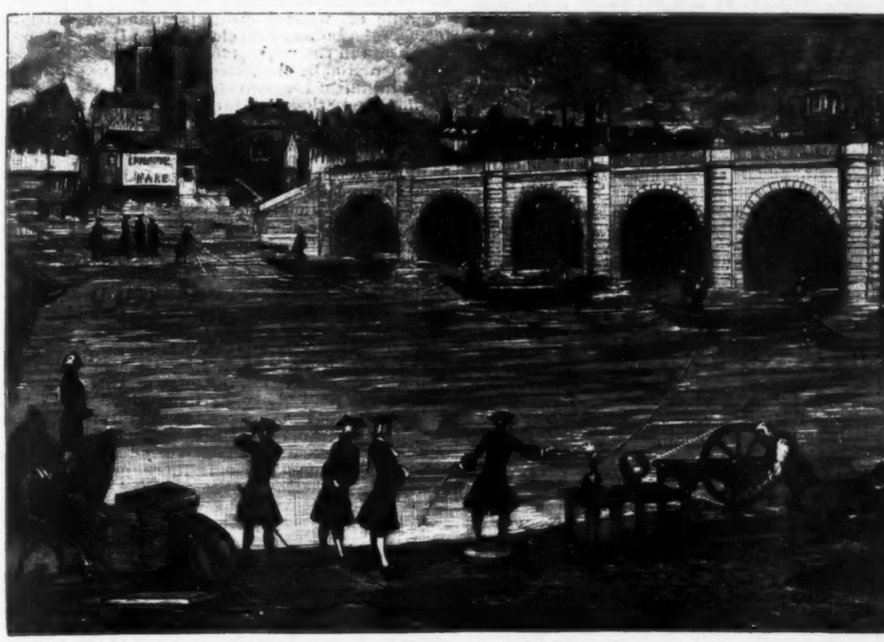
Watson, who was born in London in 1715, where he died in 1787, was one of the physicists who most contributed to the establishment of Franklin's theory and to the victory of Jenner's doctrine. He died after being created a baronet and loaded with honors. His rival was not so fortunate. Louis XV., and afterward Louis XVI., took him for an out-and-out physician, and he was named member of the Academy of Sciences; but, when the revolution came, he escaped by a miracle on the 10th of August. He was completely ruined and was obliged to open a small herbalist's shop at Montreuil, near Versailles. It was by carrying on this little trade that he escaped death by hunger—a kind of punishment still worse than that received by Lavoisier—the scaffold. Vicissitude did not disturb his good humor, and, up to 1799, the epoch at which he rendered the last sigh, he preserved the philosophy of a sage.

One cannot imagine how popular the Leyden jar became in consequence of the experiments just described. Young and old, beautiful and homely, nobles and peasants, everybody wished to take a shock. Then one began to see operators in full blast, and the owners of booths at the St. Laurent fair were seen selling electrization for a few sous. The same was the case at the permanent fair which was called the Boulevard du Temple.

Thus was soon to spring up the cabinet of Abbot Nollet, who was a member of the Academy of Sciences, and a very popular man among philosophers, as may be seen from the following incident: Voltaire, who liked neither electricity nor electricians, twice allowed him an annuity, one of £1,200 and the other of £2,000, as a mark of his esteem. This cabinet was replaced by that of Charles, who is equally well known. To these great scientific establishments must be added that of the aeronaut Robertson, which is posterior to them, and which connects them with that of Comte, Robert Houdin, Robins, Cleverman, Dickson, etc.

Of all those that are well enough known, we shall say nothing except that electricity played a large part in them; but special mention must be made of the French Museum, which was established at Marais. It is here that Pilatre de Rosier made his debut when he arrived at Paris.

Hydrogen having just been discovered, the bold Messin conceived the idea of filling his lungs with it and setting fire to it, and thus to cause a flame to issue from his breast. It is a trick that fakirs sometimes perform, but is not unattended with danger. In one of these performances Pilatre allowed the flame to reenter, and there resulted an explosion which broke two of his teeth.—*La Nature.*



EXPERIMENT IN ELECTRICITY PERFORMED BY WATSON IN THE EIGHTEENTH CENTURY.

A SUMMARY OF THE DIFFERENCE BETWEEN POSITIVE AND NEGATIVE ELECTRICITY.

IN a recent number of *La Lumiere Electrique*, M. Decharme sums up in the short article following the principal differences which have been shown to exist in the behavior of positive and negative electricity:

It has been shown by Wachter, in the *Journal de Physique*, that "in a conductor of high resistance the section which is at a mean potential is not symmetrical with respect to its two terminals, and that the higher the resistance of the conductor, the nearer to the negative terminal is this point of mean potential." With regard to mechanical effects, it is evident by Lichtemberg's figures, pierced cards, etc., that in discharges of static electricity solid or liquid substances are generally carried toward the — pole and away from the + pole, or, at any rate, more abundantly in this direction than in the other. The action of electrified points on flames may be summed up by saying that negative electricity attracts and positive electricity repels them. An electrified flame is also more powerfully attracted than a flame upon which it induces electricity. It is also well known that there is a decided difference of temperature in the poles of the voltaic arc. In air the + electrode is heated to incandescence, while the — electrode is at a lower temperature.

On the other hand, if the arc is struck in highly rarefied air, the — electrode attains the temperature of melting platinum, while the + electrode is relatively cool. If one of the electrodes is pointed and the other flat, the point becomes entirely incandescent if it is positive, but it only becomes hot at its extreme tip if it is negative. M. Semmola has devised a very striking experiment to show this phenomenon in an indirect way. He uses a fine point, made of bismuth and antimony, and thus forms a thermo-electric couple. If this point is connected to the conductor of an electric machine, a galvanometer placed in the circuit immediately shows the rise in temperature of the point, and especially so when the point is negative.

When a rather long electric spark takes place across an air gap, it sometimes spreads out near the middle, always, however, closer to the — pole than to the + pole. When the gap is lengthened, the spark frequently assumes an arborescent character, and it is observed that the lateral branches are all directed toward the — pole, showing clearly that there exists an electric tension in the body of the spark itself. Moreover, when wires are fused by an electric discharge, the fused metal is projected laterally. The hook-like shape of the electric spark obtained from the rheostatic machine of M. Gaston Plante shows that the electricity coming from the + pole meets the electricity coming from the — pole at a point close to the latter. Photographs of sparks exhibit curious differences, characteristic of the two electricities. In 1877, M. A. Righi published a lengthy memoir, entitled, "Ricerche Sperimentali sulla Scariche Electriche," in which are given numerous illustrations of the electric spark, copied from photographs taken under different conditions by the author. The characteristics of the two discharges are here clearly delineated; the positive discharges being spread out, the negative being more concentrated. The same memoir also contains an illustrated description of the various forms taken by the electric spark in air and liquids, showing most perfectly the difference in shape and color presented by the two electricities.

As to the induction spark, it consists of two streams and an aureola. In air, at ordinary pressure, the positive and negative brushes display differences arising from the inequality of potential at the moment of discharge. These differences become less accentuated as the air becomes more rarefied. The hook-like brush shows the same peculiarities as the spark. In a partial vacuum the difference between positive and negative electricity is very marked by the color of the glow around the two poles, by the shape of this glow, and above all—and this more especially when an induction coil is used—by the presence of striæ. These phenomena are much affected by the medium. In a complete vacuum the purple glow seems to move in the same direction as the positive discharge.

Another fact not less important, which ought to be kept in mind, is that in vaccuum tubes and with sufficiently powerful E.M.F.'s, the striæ are always turned in the same direction with the convex side toward the — pole. This phenomenon is analogous to that which is presented where a gas makes its way through a liquid, which it never does in a continuous stream, but always in bubbles more or less large according to the pressure. In the same way electricity, when it penetrates a gaseous medium more or less rarefied, does not pass through it in an unbroken stream, but in a vibratory manner. In this way perhaps the phenomenon of striæ can be explained mechanically, for it is produced with continuous currents as well as with intermittent or alternating currents.

In air at ordinary pressure we can say, so far as regards potential, loss of charge, and propagation, that negative electricity is always at a lower potential than positive electricity, that a negative charge is more rapidly dissipated than a positive, that negative electricity is more easily propagated than positive. The contrary holds good in a disruptive discharge, when positive electricity has the greater tendency to discharge through the air. In rarefied air these differences disappear, whether high potentials or large currents are employed. There is, therefore, nothing ab-

solute about these tendencies, as they depend entirely on the experimental conditions. This, however, does not render these differences more easy of explanation.

In physiological effects the direction of the current is of supreme importance. When a continuous current, acting on a motor nerve, is propagated in the same direction as the nerve ramifications, *i. e.*, from the center outward, it produces a contraction at the moment of closing the circuit and a sense of pain at the moment of breaking the circuit, and the direction of the current being reversed, a painful sensation on closing and contraction on breaking the circuit. When we operate on a sensory nerve the opposite takes place. Finally, if a current paralyzes a muscle, we need only reverse its direction in order to restore its contractile power. We cannot do better than compare the contraction of a muscle at the moment of breaking the circuit to the recoil which takes place in a long water pipe when the flow of water is suddenly arrested by the closing of a tap.

THE EFFECT OF LIGHT ON MATTER.*

By Captain W. De W. Abney.

The occupant of this chair has a difficult task to perform, should he attempt to address himself to all the various subjects with which this section is supposed to deal. I find that it has very often been the custom that some one branch of science should be touched upon by the president, and I shall, as far as in me lies, follow this procedure.

This year is the jubilee of the practical introduction of photography by Daguerre and Fox Talbot, and I have thought I might venture to take up your time with a few remarks on the effect of light on matter.

I am not going into the history of photography, nor to record the rivalries that have existed in regard to the various discoveries that have been made in it. A brand-new history of photography, I dare say, would be interesting, but I am not the person to write one; and I would refer those who desire information as to facts and dates to histories which already exist. In foreign histories, perhaps, we English suffer from speaking and writing in a language which is not understanded of the foreign people; and the credit of several discoveries is sometimes allotted to nationalities who have no claim to them. Be that as it may, I do not propose to correct these errors or to make any reclamations. I leave that to those whose leisure is greater than mine.

I have often asserted, and I again assert, that there should be no stimulus for the study of science to be compared to photography. Step by step, as it is pursued, there will be formed a desire for a knowledge of all physical science. Physics, chemistry, optics, and mathematics are all required to enable it to be studied as it should be studied: and it has the great advantage that experimental work is the very foundation of it, and results of some kind are always visible. I, perhaps, am taking an optimist view of the matter, seeing that there are, at least, 25,000 living facts against my theory, and perhaps not 1 per cent. of them in its favor. I mean that there are, at least, 25,000 persons who take photographs, and scarcely 1 per cent. who know or care anything of the "why or wherefore" of the processes, so far as theory is concerned. If we call photography an applied science, it certainly has a larger number who practice it, and probably fewer theorists, than any other.

PHOTOGRAPHIC ACTION OF LIGHT ON MATTER.

He would be a very hardy man who would claim for Niepce, Daguerre, or Fox Talbot the discovery of photographic action on matter. The knowledge that such an action existed is probably as old as the fair-skinned races of mankind, who must have recognized the fact that light, and particularly sunlight, had a tanning action on the epidermis, and the women then, as now, no doubt, took their precautions against it. As to what changes the body acted upon by light underwent, it need scarcely be said that nothing was known, and perhaps the first scientific experiment in this direction was made rather more than a hundred years ago by Scheele, the Swedish chemist, who found that when chloride of silver was exposed to light, chlorine was given off.

It was not till well in the forties that any special attention was given to the action that light had on a variety of different bodies; and then Sir John Herschel, Robert Hunt, Becquerel, Draper, and some few others carried out experiments which may be termed classical. Looking at the papers which Herschel published in the Philosophical Transactions and elsewhere, it is not too much to say that they teem with facts which support the grand principle that without the absorption of radiation no chemical action can take place on a body; in other words, we have in them experimental proofs of the law of the conservation of energy. Hunt's work, "Researches on Light," is still a text-book to which scientific photographers refer, and one is sometimes amazed at the amount of experimental data which is placed at our disposal. The conclusions that Hunt drew from his experiments, however, must be taken with caution in the light of our present knowledge, for they are often vitiated by the idea which he firmly held, that radiant heat, light, and chemical action, or actinism, were each of them properties, instead of the effects, of radiation. Again, we have to be careful in taking seriously the experiments carried out with light of various colors when such colors were produced by absorbing media. It must be remembered that an appeal to a moderately pure spectrum is the only appeal which can be legitimately made as to the action of the various components of radiation, and even then the results must be carefully weighed before any definite conclusions can be drawn. No photographic result can be considered as final unless the experiments be varied under all the conditions which may probably arise. Colored media are dangerous as enabling trustworthy conclusions to be drawn, unless the characters of such media have been thoroughly well tested and the light they transmit has been measured. An impure spectrum is even more dangerous to rely upon, since the access of white light would be sure to vitiate the results.

Perhaps one of the most puzzling phenomena to be met with in photography is the fact that the range of photographic action is spread over so large a portion of the spectrum. The same difficulty of course is felt in the matter of absorption, since the one is dependent on the other. Absorption by a body we are accustomed, and indeed obliged by the law of the conservation of energy, to consider as due to the transference of the energy of the ether wave motion to the molecules and atoms comprising the body by increasing the vibrations of one or both.

CHEMICAL ACTION.

In the case where chemical action takes place we can scarcely doubt that it is the atoms which in a great measure take up the energy of the radiation falling on them, as chemical action is dependent on the liberation of one or more atoms from the molecule, while, when the swings of the molecules are increased in amplitude, we have a rise in temperature of the body. I shall confine the few remarks I shall make on this subject to the case of chemical action. The molecule of a silver salt, such as bromide of silver, chemists are wont to look upon as composed of a limited and equal number of atoms to form the molecule. When we place a thin slab of this material before the slit of the spectroscope we find a total absorption in the violet and ultra-violet of the spectrum and a partial absorption in the blue and green, and a diminishing absorption in the yellow and red.

A photographic plate containing this same salt is acted upon in exactly the same localities and in the same relative degree as where the absorption takes place. Here, then, we have an example of, it may be, the vibrations of four atoms, one of which at least is isochronous, or partially so, with the waves composing a large part of the visible spectrum. The explanation of this is somewhat obscure. A mental picture, however, may help us. If we consider that, owing to the body acted upon being a solid, the oscillations of the molecules and atoms are confined to a limited space, it probably happens that between the times in which the atoms occupy, in regard to one another, the same relative positions, the component vibrations of say two of the atoms vary considerably in period. An example of what I mean is found in a pendulum formed of a bob and an elastic rod. If the bob be made to vibrate in the usual manner, and at the same time the elastic rod be elongated, it is manifest that we have a pendulum of ever-varying length. At each instant of time the period of vibration would differ from that at the next instant, if the oscillations were completed. It is manifest that increased amplitude would be given to the pendulum swings by a series of well-timed blows differing very largely in period; at the same time there would be positions of the pendulum in which some one series of well-timed blows would produce the greatest effect. In a somewhat similar manner we should imagine that the ethereal waves should produce increased amplitude in the swing of the atoms between very wide limits of period, and further that there should be one or more positions in the spectrum when a maximum effect is produced.* I would here remark that the shape of the curves of sensitiveness, when plotted graphically, of the different salts of silver to the spectrum have a marked resemblance to the graphically drawn curves of the three color sensations of the normal eye, as determined by Clerk Maxwell. May not the reason for the form of the one be equally applicable for the other? I only throw this out as evidence, not conclusive indeed, that the color sensitiveness of the eye is more probably due to a photographic action on the sensitive retina than to a merely mechanical action. That this is the case I need scarcely say has several times been propounded before.

DECOMPOSITION OF SILVER SALTS.

The ease with which a silver salt is decomposed is largely, if not quite, dependent on the presence of some body which will take up some of the atoms which are thrown off from it. For instance, in chloride of silver we have a beautiful example of the necessity of such a body. In the ordinary atmosphere the chloride is of course colored by the action of light; but if it be carefully dried and purified, and placed in a good vacuum, it will remain uncolored for years in the strongest sunlight. In this case the absence of air and moisture is sufficient to prevent it discoloring.

If in the vacuum, however, a drop of mercury be introduced, the coloration by light is set up. We have the chlorine liberated from the silver and combining with the mercury vapor, and a minute film of calomel formed on the sides of the vessel.

Delicate experiments show that not only is this absorbent almost necessary when the action of light is so strong or so prolonged that its effect is visible, but also when the exposure or intensity is so small that the effect is invisible and only to be found by development. The reason for this absorbent is not far to seek. If, for instance, silver chloride be exposed to light *in vacuo*, although the chloride atoms may be swung off from the original molecule, yet they may only be swung off to a neighboring molecule which has lost one of its chlorine atoms, and an interchange of atoms merely takes place. If, however, a chlorine absorbent be present which has a greater affinity for chlorine than has the silver chloride which has lost one of its atoms, then we may consider that the chlorine atoms will be on the average more absorbed by the absorbent than by the subchloride molecules. The distribution of the swung-off atoms between the absorbent and the subchloride will doubtless be directly proportional to their respective affinities for chlorine, and so for the other salts of silver. If this be so, then it will be seen that the greater the affinity of the absorbent for the halogen, the more rapid will be the decomposition of the silver salt. This, then, points to the fact that if any increase in the sensitiveness of a silver salt is desired, it will probably be brought about by mixing with it some stronger halogen absorbent than has yet been done.

The question as to what is the exact product of the decomposition of a silver salt by the action of light is one which has not as yet been fully answered. For my own part, I have my strong beliefs and my disbeliefs. I fully believe the first action of light to be a very simple one, though this simple action is masked by other actions taking place, due to the surroundings in which it takes place. The elimination of one atom from a molecule of a silver salt leaves the molecule in an unsatisfied condition, and capable of taking up some fresh atom. It is this capacity which seemingly shrouds the first action of light, since when exposure is prolonged the molecules take up atoms of oxygen from the air or from the moisture in it. Carey Lea, of Philadelphia, has within the last three years given some interesting experiments on the composition of what he calls the photo-chloride of silver, which is the chloride colored by light, and Prof. Hodgkinson has also taken up the matter. The conclusions the former has drawn are, to my mind, scarcely yet to be accepted. According to the latter experimentalist, the action of light on silver chloride is to form an oxidized subsalt. This can hardly be the case, except under certain conditions, since a colored compound is obtained when the silver chloride is exposed in a liquid in which there is no oxygen present.

PHOTOGRAPHY IN NATURAL COLORS.

This coloration by light of the chloride of silver naturally leads our thoughts to the subject of photography in natural colors. The question is often asked when photography in natural colors will be discovered. Photography in natural colors not only has been discovered, but pictures in natural colors have been produced. I am not alluding to the pictures produced by manual work, and which have from time to time been foisted on a credulous public as being produced by the action of light itself, much to the damage of photography and usually of the so-called inventors. Roughly speaking, the method of producing the spectrum in its natural colors is to chlorinize a silver plate, expose it to white light till it assumes a violet color, heat till it becomes rather ruddy, and expose it to a bright spectrum. The spectrum colors are then impressed in their natural tints. Experiment has shown that these colors are due to an oxidized product being formed at the red end of the spectrum and a reduced product at the violet end. Photography in natural colors, however, is only interesting from a scientific point of view, and, so far as I can see, can never have a commercial value.

A process to be useful must be one by which reproductions are quickly made; in other words, it must be a developing and not a printing process, and it must be taken in the camera, for any printing process requires not only a bright light, but also a prolonged exposure. Now it can be conceived that in a substance which absorbs all the visible spectrum the molecules can be so shaken and sifted by the different rays that eventually they sort themselves into masses which reflect the particular rays by which they are shaken; but it is almost—I might say, quite—impossible to believe that when this sifting has only been commenced, as it would be in the short exposure to which a camera picture is submitted, the substance deposited to build up the image by purely chemical means would be so obliging as to deposit in that the particular size of particle which should give to the image the color of the nucleus on which it was depositing. I am aware that in the early days of photography we heard a good deal about curious results that had been obtained in negatives, where red brick houses were shown as red and the blue sky as bluish. The cause of these few coincidences is not hard to explain, and would be exactly the same as when the red brick houses were shown as bluish and the sky as red in a negative. The records of the production of the latter negatives are naturally not abundant, since they would not attract much attention. I may repeat, then, that photography in natural colors by a printing-out process—by which I mean by the action of light alone—is not only possible, but has been done, but that the production of a negative in natural colors from which prints in natural colors might be produced appears, in the present state of our knowledge, to be impossible. Supposing it were not impracticable, it would be unsatisfactory, as the light with which the picture was impressed would be very different from that in which it would be viewed. Artists are fully aware of this difficulty in painting, and take their precautions against it.

The nearest approach to success in producing colored pictures by light alone is the method of taking three negatives of the same subject through different colored glasses, complementary to the three color sensations which together give to the eye the sensations of white light. The method is open to objection on account of the impure color of the glasses used. If a device could be adopted whereby only those three parts of the spectrum could be severally used which form the color sensations, the method would be more perfect than it is at present. Even then perfection could not be attained, owing to a defect which is inherent in photography, and which cannot be eliminated. This defect is the imperfect representation of gradation of tone.

For instance, if we have a strip graduated from what we call black to white (it must be recollected that no tone can scientifically be called black, and none white) and photograph it, we shall find that in a print from the negative the darkness which is supposed to represent a gray of equal mixtures of black and white by no means does so unless the black is not as black nor the white as white as the original. The cause of this untruthfulness in photography has occupied my attention for several years, and it has been my endeavor to find out some law which will give us the density of a silver deposit on a negative corresponding with the intensity of the light acting. I am glad to say that at the beginning of this year a law disclosed itself, and I find that the transparency of a silver deposit caused by development can be put into the form of the law of error.

This law can be scarcely empiric, though at first sight it appears that the manipulations in photography are so loose that it should be so. It is this very looseness, however, which shows that the law is applicable, since in all cases I have tried it is obeyed. That there are theoretical difficulties cannot be denied, but it is believed that strictly theoretical reasoning will eventually reconcile theory with observation.

This want of truth in photography in rendering graduation, then, puts it out of the range of possibility that photography in natural colors can ever be exact, or that the three negatives system can ever get over the difficulty.

ORTHOCHROMATIC PHOTOGRAPHY.

One of the reproaches that in early days was cast at

* Opening address by Captain W. De W. Abney, C.B., R.E., F.R.S., F.R.A.S., President of Section A, Mathematics and Physics, British Association, Newcastle, 1889.

* The effect of perfect and nearly perfect synchronism of one oscillation upon another is also to be found exemplified in my "Treatise on Photography" ("Text-book of Science Series").

photography was its inability to render color in its proper monochromatic luminosity. Thus while a dark blue was rendered as white in a print—that is, gave a dense deposit in a negative—bright yellow was rendered as black in a print, or nearly so—that is, as transparent or nearly transparent glass in the negative. To the eye the yellow might be far more luminous than the blue, but the luminosity was in the photograph reversed. I need hardly say that the reason of this want of truth in the photograph is due to the want of sensitiveness of the ordinarily used silver salts to the least refrangible end of the spectrum.

Some fifteen years ago Dr. H. W. Vogel announced the fact that when silver salts were stained with certain dyes, they became sensitive to the color of the spectrum which the dyes absorbed. This at once opened up possibilities, which, however, were not at once realized, owing perhaps to the length of exposure required when the collodion process was employed. Shortly after the gelatine process was perfected, the same dyes were applied to plates prepared by this method, which although they contained the same silver salts as the old collodion process, yet *per se* were very much more sensitive. A new era then dawned for what has been termed isochromatic and orthochromatic photography.

The dyes principally used are those belonging to the eosin group and cyanine—not the ordinary cyanine dye of commerce, but that discovered by Greville Williams. For a dye to be of use in this manner it may be taken as an axiom—first propounded by the speaker, it is believed—that it must be fugitive, or that it must be capable of forming a silver compound. The more stable a dye is, the less effective it is. If we take as an example cyanine, we find that it absorbs in the orange and slightly in the red. If paper or collodion stained with this coloring matter be exposed to the action of the spectrum, it will be found that the dye bleaches in exactly the same part of the spectrum as that in which it absorbs, following, indeed, the universal law I have already alluded to.

If a film containing a silver salt be dyed with the same, it will be found that, while the spectrum acts on it in the usual manner—viz., darkening it in the blue, violet, and ultra-violet—the color is discharged where the dye absorbs, showing that in one part of the spectrum it is the silver salt which is sensitive, and that in the other it is the coloring matter. If such a plate, after exposure to the spectrum, be developed, it will be found that at both parts a deposit of silver takes place; and further, when the experiment is carefully conducted, if a plate with merely cyanine colored collodion be exposed to the spectrum and bleached in the orange, and after removal to the dark room another film containing a silver salt be applied and then a developer, a deposit of silver will take place where the bleaching has occurred.

This points to the fact that the molecules of a fugitive dye, when altered by light, are unsatisfied, and are ready to take up an atom or atoms of silver, and other molecules of silver will deposit on such nuclei by an action which has various names in physical science, but which I do not care to mention. This is the theory which I have always advocated, viz., that the dye by its reduction acts as a nucleus on which a deposit of silver can take place. It met with opposition; a rival theory which makes the dye an "optical sensitizer"—an expression which is capable of a meaning which I conceive contrary to physical laws—being run against it.

The objection to what I may call the nucleus theory is less vigorous than it has been, and its diminution is due perhaps to the more perfect understanding of the meaning of each other by those engaged in the controversy. To my mind, the action of light on fugitive dyes is one of the most interesting in the whole realm of photography, as eventually it must teach us something as to the structure of molecules, and add to the methods by which their coarseness may be ascertained. Be the theory what it may, however, a definite result has been attained, and it is now possible to obtain a *fair* representation of the luminosity of colors by means of dyed films. At present the employment of colored screens in front of the lens, or on the lens itself, is almost an essential in the method when daylight is employed; but not till some dye is discovered which shall make a film equally sensitive for the same luminosity to the whole visible spectrum will it be possible to make orthochromatic photography as perfect as it can be made. The very fact that no photograph of even a black and white gradation will render the latter correctly must of necessity render any process imperfect, and hence in the above sentence I have used the expression "as perfect as it can be made."

PHOTOGRAPHY OF THE SPECTRUM.

The delineation of the spectrum is one of the chief scientific applications to which photography has been put. From very early days the violet and ultra-violet end of the spectrum have been favorite objects for the photographic plate. To secure the yellow and red of the spectrum was, however, till of late years, a matter of apparently insurmountable difficulty; while a knowledge of that part of the spectrum which lies below the red was only to be gained by its heating effect. The introduction of the gelatine process enabled the green portion of the spectrum to impress itself on the sensitive surface; while the addition of various dyes, as before mentioned, allowed the yellow, the orange, and a portion of the red rays to become photographic rays. Some eight years ago it was my own good fortune to make the dark infra-red rays impress themselves on a plate. This last has been too much a specialty of my own, although full explanations have been given of the methods employed. By preparing a bromide of silver salt in a peculiar manner, one is able so to modify the molecular arrangement of the atoms that they answer to the swings of those waves which give rise to these radiations. By employing this salt of silver in a film of collodion or gelatine the invisible part of the spectrum can be photographed and the images of bodies which are heated to less than red heat may be caused to impress themselves upon the sensitive plate. The greatest wave length of the spectrum to which this salt is sensitive so far is 22,000 λ, or five times the length of the visible spectrum. The exposure for such a wave length is very prolonged, but down to a wave length of 12,000 it is comparatively short, though not so short as that required for the blue rays to impress themselves on a collodion plate. The color of the sensitive salt is a green blue by transmitted light; it has yet to be determined whether this color is all due to coarseness of the particles or to the absorption by the molecules. The fact that a film can be prepared which by transmitted light is yellow, together with an absorption of the red and orange, points to the green color being probably due to absorption by the molecules. We have thus in photography a means of recording phenomena in the spectrum from the ultra-violet to a very large wave length in the infra-red—a power which physicists may some day turn to account. It would, for instance, be a research worth pursuing to photograph the heavens on a plate prepared with such a salt, and search for stars which are nearly dead or newly born, for in both cases the temperature at which they are may be such as to render them below red heat, and therefore invisible to the eye in the telescope. It would be a supplementary work to that being carried out by the brothers Henri, Common, Roberts, Gill, and others, who are busy securing photographic charts of the heavens in a manner which is beyond praise.

QUANTITATIVE MEASUREMENTS.

There is one other recent advance which has been made in scientific photography to which I may be permitted to allude, viz., that from being merely a qualitative recorder of the action of light it can now be used for quantitative measurement. I am not now alluding to photographic actinometers, such as have been brought to such a state of perfection by Roscoe; but what I allude to is the measurement and interpretation of the density of deposit in a negative. By making exposures of different lengths to a standard light, or to different known intensities of light, on the same plate on which a negative has to be taken, the photographic values of the light acting to produce the densities on the different parts of the developed image can be readily found. Indeed, by making two different exposures to the same light, or two exposures to two different intensities of light, and applying the law of density of deposit in regard to them, a curve is readily made from which the intensities of light necessary to give the different densities of deposit in the image impressed on the same plate can be read off. The application of such scales of density to astronomical photographs, for example, cannot but be of the highest interest, and will render the records so made many times more valuable than they have hitherto been. I am informed that the United States astronomers have already adopted the use of such scales, which for the last three years I have advocated, and it may be expected that we shall have results from such scaled photographs which will give us information which would before have been scarcely hoped for.

One word as to a problem which we may say is as yet only qualitatively and not quantitatively solved. I refer to the interchangeability of length of exposure for intensity of light. Put it in this way. Suppose that with a strong light, L, a short exposure, E, be given, a chemical change, C, is obtained; will the same change, C, be obtained if the time is only an nth of the light, L, but n times the exposure? Now this is a very important point, more particularly when the body acted upon is fairly stable, as, for instance, some of the water-color pigments, which are known to fade in sunshine, but might not be supposed to do so in the light of an ordinary room, even with prolonged exposure. Many experiments have been made at South Kensington as regards this, more especially with the salts of silver, and it is found that, for an ordinary light, intensity and exposure are interchangeable, but that when the intensity of light is very feeble, say the $\frac{1}{1000000}$ of ordinary daylight, the exposure has to be rather more prolonged than it should be, supposing the exact interchangeability always held good; but it has never been found that a light was so feeble that no action could take place. Of course it must be borne in mind that the stability of the substance acted upon may have some effect; but the same results were obtained with matter which is vastly more stable than the ordinary silver salts. It may be said in truth that almost all matter which is not elemental is, in time and to some degree, acted upon by light.

I should like to have said something regarding the action of light on the iron and chromium salts, and so introduce the subject of platinotype and carbon printing, the former of which is creating a revolution in the production of artistic prints. I have, however, refrained from so doing, as I felt that the president of Section A should not be mistaken as the president of Section B. Photogravure and the kindred processes were also inviting subjects on which to dwell, more especially as at least one of them is based on the use of the same material as that on which the first camera picture was taken by Niépce. Again, a dread of trenching on the domains of art restrains me.

Indeed, it would have been almost impossible, and certainly impolitic, in the time which an address should occupy, to have entered into the many branches of science and art which photography covers. I have tried to confine myself to some few advances that have been made in its theory and practice.

The discovery of the action of light on silver salts is one of the marvels of this century, and it is difficult to overrate the bearing it has had on the progress of science, more especially physical science. The discovery of telegraphy took place in the present reign, and two years later photography was practically introduced; and no two discoveries have had a more marked influence on mankind. Telegraphy, however, has had an advantage over photography in the scientific progress that it has made, in that electrical currents are subject to exact measurement, and that empiricism has no place with it. Photography, on the other hand, has labored under the disadvantage that, though it is subject to measurement, the factors of exactitude have been hitherto absent. In photography we have to deal with molecules the equilibrium of whose components is more or less indifferent according to the process used; again, the light employed is such a varying factor that it is difficult to compare results. Perhaps more than any other disadvantage it labors under is that due to quackery of the worst description at the hands of some of its followers, who not only are self asserting, but often ignorant of the very first principles of scientific investigation. Photography deserves to have followers of the highest scientific caliber; and if only some few more real physicists and chemists could be induced to unbend their minds and study the theory of an applied science which they often use for record or for pleasure, we might hope for some greater advance than has hitherto been possible.

Photography has been called the handmaid of art; I venture to think it is even more so the handmaid of science, and each step taken in perfecting it will render it more worthy of such a title.

COLLOIDAL CELLULOSE.

A PAPER has been read recently before the French Academy of Sciences, by M. Ch. E. Guignet, upon a form of cellulose which may be of use in photography, and which has already pressed so many of the colloids into important portions of its service. M. Guignet's memoir sets forth that he begins with pure cellulose —preferably the filtering paper prepared by cleansing with hydrochloric and hydrofluoric acids, for use in analysis; the finest carded cotton wool will also answer, but the final products obtained have then a slightly gray color. He dries the selected cellulose, and then soaks it in sulphuric acid of the strength 50° B., which transforms it into a transparent gelatinous mass, which keeps indefinitely in that condition, even in the presence of excess of acid, when the temperature is not allowed to rise. At 100° C., or even less, the transformation into dextrine is very rapid.

Treated with water and thoroughly washed, the colloid cellulose will dissolve in *pure* water. To readily remove the last traces of acid, it is advantageous to wash it with ordinary alcohol, and then to dry it by a gentle heat almost to the total evaporation of the residue of spirit. On again treating it with water, a slightly milky liquid is obtained, which deposits nothing, even when allowed to stand for several days. The liquid is not altered by being boiled, and the colloid cellulose is slightly more soluble in hot than in cold water. By transmitted light the solution has an almost pure orange color.

As is the case with several colloid substances, colloidal cellulose is precipitated from its solution by the addition of very small quantities of foreign matters, such as sulphuric acid, nitric acid, chloride of sodium, sulphate of soda, and acetate of lead. A sufficient quantity of alcohol also determines the precipitation. It is not thrown down by the tartrate of copper and soda; it is not colored by iodine, and differs completely from those dextrines which are not thrown down by acetate of lead and small quantities of foreign salts.

When dried on a clean marble slab previously rubbed over with vaseline, colloid cellulose gives a brilliant semi-transparent pellicle, which first swells slightly in cold water, and then dissolves completely. A milky liquid like the original is thus again obtained. If dipped for a few instants in sulphuric acid of 60° B., or even of 55° B., if the immersion be more prolonged, the colloid cellulose become insoluble in water; at the same time a small quantity of dextrine is formed. Well dried colloid cellulose is changed by nitric acid in the same way that ordinary cotton is changed.

M. Guignet adds that the properties of colloid cellulose furnish an explanation of several peculiarities appertaining to parchment paper. Some very thin varieties of the latter give up colloidal cellulose to boiling water. On the other hand, stronger papers are not attacked under the same conditions, no doubt because a stronger acid was employed in the manufacture, rendering the colloidal cellulose insoluble. Parchment paper represents to some extent ordinary paper with its pores filled with colloidal cellulose. This can easily be proved by coating ordinary filtering paper on both sides with colloidal cellulose, allowing it to dry slowly, and then rolling it under pressure between two sheets of polished zinc, as in satining paper. The product exactly resembles vegetable parchment similarly rolled. M. Guignet says that among the natural products previously studied, none resembles colloidal cellulose; pectic substances, gelose, and others differ from it in most essential characteristics; for instance, solutions of these substances are not precipitated by small additions of foreign matters.

From the chemical constitution of the substance made by M. Guignet, it may be expected to resist the action of damp much better than gelatine and colloids at present in use in photography, assuming it to be, as he says, but cellulose in an unfamiliar form. Its manufacture on a large scale is manifestly cheap, because the only dear substance used is alcohol, which, for the most part, can be recovered by distillation. Films of the colloidal cellulose have the property of being easily made soluble or insoluble at the will of the operator, and it is a substance likely to be as inert as pure filtering paper to the action of salts of silver. Altogether, this new discovery seems likely enough to have a more important bearing upon some photographic processes of the future than can at present be seen.—*Photo. News.*

THE NATURE OF SOLUTIONS.

By S. U. PICKERING, M.A.

I BEG to announce that I have this day succeeded in isolating in the solid crystalline form one of the hydrates of sulphuric acid, the existence of which in solutions I had lately predicted from a study of the densities and heat of dissolution of sulphuric acid solutions of different strengths (*Proc. Chem. Soc.*, 1889, 88; and *Chemical News*, lix., 249). The new hydrate is $H_2SO_4.4H_2O$, containing 57·66 per cent. of acid. The proof of its existence depends on its having a definite melting point at —25°, which is lowered (as far as about — 70°) by the addition of excess of either water or sulphuric acid, and on other evidence which it is not convenient to give in the present place. The isolation of one of the hydrates with either 2, 4, 5, or 9 H_2O had been rendered probable by a study of the freezing points of sulphuric acid solutions, and the nature of the curves representing the freezing points of solutions from which the tetrahydrate crystallizes renders it highly improbable that any other hydrate will be obtained in the solid form except, of course, the monohydrate, which has long been known. Such an absolute proof of the conclusions which I have drawn from other sources must place those conclusions beyond doubt, and must establish as an incontestable fact the existence of hydrates in solution.—*Chem. News.*

PASTEURIZATION OF FERMENTABLE LIQUIDS.

IN class 50 of the Machinery Palace of the French exposition, the Industrial Company of the Raoul Pictet Processes exhibits, along with its machines for the production of cold, an apparatus for pasteurizing beer and other fermentable liquids according to the process of W. Kuhn. We propose to speak, before long, of the first mentioned of these, which have been the object of some recent improvements, but it seems

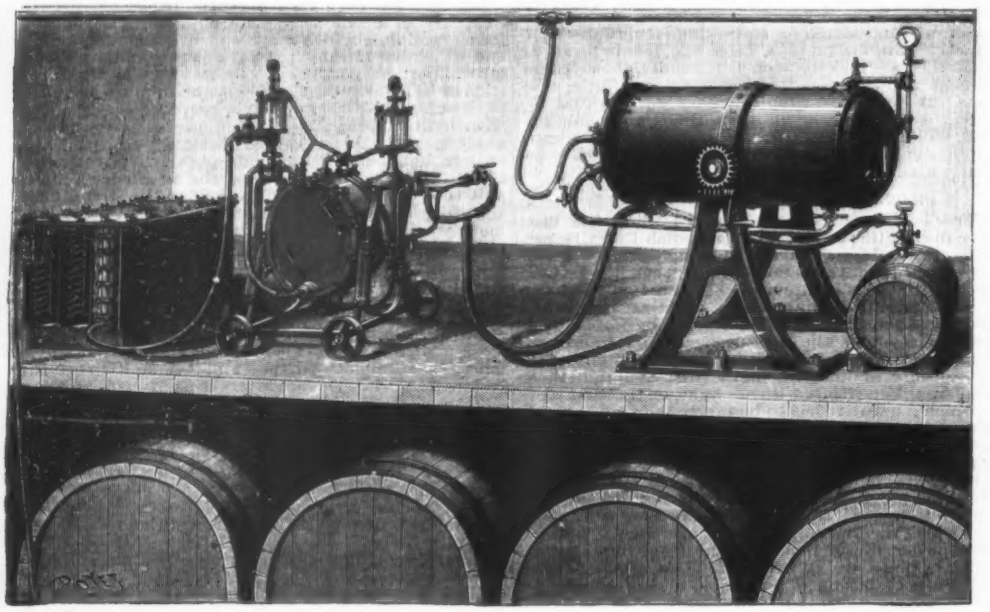


FIG. 1.—INSTALLATION OF THE KUHN APPARATUS FOR THE PASTEURIZATION OF BEER.

to us well to describe, without further delay, the second, which is of the type 5*h*, and is adapted to the treatment of liquids in casks.

As the name indicates, the Kuhn process is based upon the method discovered by Mr. Pasteur in the course of his remarkable study of ferments. This eminent chemist has observed that a beer heated to a temperature of from 55° to 60°, under peculiar conditions, no longer favors the development and multiplication of the microscopic organisms that are the ferments of disease, but becomes unalterable, whatever be the temperature of its manufacture and preservation.

This observation is of great importance to breweries, which were formerly unable to produce a beer of durable limpidity without the use of costly or dangerous methods. A long storage in cold cellars gives good results, it is true, but, considering the large installations that it requires, this means is not within the reach of small and medium sized establishments. The use of antiseptics has likewise been extolled. Every one still remembers the discussions that salicylated beers raised among physicians and hygienists. Antiseptics, besides, are capable of changing the natural taste of the beer. More recently, filtering has rendered important services in breweries; but, although it yields a beer of perfect limpidity, the latter soon alters under the effect of a further fermentation. In fact, whatever be their mode of construction, filters do not destroy the germs of ferments; they do, indeed, arrest the greatest part of them along with the bodies in suspension, but the microscopic organisms pass through the densest porous masses, and soon multiply anew.

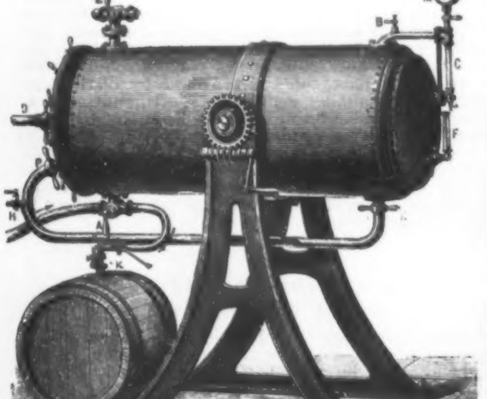


FIG. 2.—KUHN PASTEURIZING APPARATUS.

It is by combining filtration with pasteurization that it has been found possible to realize the only physical means known, up to the present, of sterilizing fermentable liquids, while at the same time preserving the primitive aroma obtained by the brewer.

As simple as the heating of beer appears in principle, it requires certain indispensable precautions to make the operation a success. That is why this method has been applied with success up to the present only to the treatment of bottled beer. Great difficulties arise, in fact, when it is necessary to heat large quantities of beer uniformly and to cool them very rapidly and put them in casks so as to exclude them from contact with the air. Numerous attempts have been made to surmount these difficulties; but of the various solutions of the problem, the one due to Mr. Kuhn is the most elegant, and constitutes, as a whole, a process of manipulating the beer and an apparatus for carrying the process out.

The following are the multiple conditions that are required by the perfect pasteurization of beer, applied to volumes of 110, 220, and 440 gallons:

The individual mass must be heated rapidly in a homogeneous manner, so as to prevent any portion from attaining a higher or lower temperature than the normal degree of the operation. The alteration suffered by the superheated portions, through too long a period of heating, would, in fact, lead to that disagreeable taste called pasteurization flavor, and, on another hand, some of the portions not heated to 60° would contain non-sterilized ferments.

In addition to the regular and rapid carrying on of the heating, it is necessary that the vessel in which the operation is performed shall have a large surface of contact with the beer, so that it shall have at no point a temperature exceeding the normal heat of the operation. In this way are prevented the movements of the carbonic acid from one part of the beer to the other, for the elements of the unstable combinations that may have made a beginning toward dissociation find themselves in presence in the same proportions and recombine during the cooling. Such a condition failing, the beer would still be apt to take on a bad taste.

Lastly, the cooling requires to be done with rapidity and under protection from the air, in order to prevent the deposit of new active ferments.

All such desiderata can be easily realized in the pasteurization of bottled beer. It suffices, in fact, to immerse a certain number of the bottles, by means of a windlass, in a water bath heated to the proper temperature, to cork them afterward, and then to lower them into a cellar, where the cooling rapidly proceeds. But, as may be conceived, this treatment, of which the results are excellent, is scarcely applicable to large

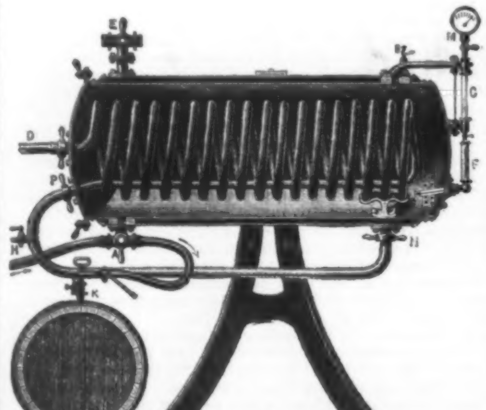


FIG. 3.—LONGITUDINAL SECTION.

breweries, where it is necessary to be able to operate upon liquids in large quantities before putting them in casks for shipment.

The Kuhn process and apparatus permit of obtaining such an industrial result, and what contributes to the latter in a large measure is the use, as a cooling agent, of an uncongealable liquid or of any other source of artificial cold capable of reaching about −19° C. In fact, numerous experiments have shown that after the beer has been submitted, for the time strictly necessary, to the temperature of pasteurization, its rapid and abrupt cooling favors the reconstitution of the unstable compounds that have begun to separate under the action of the heat.

Now the uncongealable liquid (chloride of magnesium or calcium) is much more efficacious than cold water or ice water, and it acts upon the very wide surfaces of contact that have served for the heating of the beer. For all these reasons, the cooling of the beer proceeds under exceptional conditions of rapidity.

This explains the motive that induced the company above mentioned to join with its industry the application of the Kuhn process in breweries. The brewer can, in fact, with the same frigerific agent, cool his fermenting and preserving tuns and supply the pasteurizing apparatus.

Fig. 1 gives a general view of an installation for the treatment of beer by means of the Kuhn apparatus, which is represented on a larger scale in Figs. 2 and 3.

It is well to establish this laboratory near the storage cellars. It consists of a special refrigerator, of a Stockheim filter for freeing the beer of the major part of the active ferments, and of a Kuhn pasteurizer. The latter consists of a horizontal copper cylinder closed at one extremity by a movable bottom, and at the other by a fixed one carrying a pressure gauge, M, a water level, C, and a metallic thermometer, F. This cylinder has tight joints and a double iron plate jacket. At B there is a cock for letting out the air during the filling.

A copper worm starts from the movable bottom, occupies the entire length of the cylinder, and debouches on the same side, where it is connected through the cocks, P and N, with the jacket of the cylinder. On another hand, it communicates, through the two-way cock, E, either with the hot water reservoirs or with the return pipe of the uncongealable liquid.

As for the beer that fills the cylinder, the entrance and exit of that are regulated by the two-way cock, A.

An iron plate hoop, surrounding the center of the cylinder, is provided with trunnions, which are supported by two cast iron uprights, and around which the apparatus may be revolved upon actuating the switch of an endless screw gearing. A reservoir supplies this apparatus with hot water for raising the beer to the desired temperature, and which enters at D (Figs. 2 and 3), and circulates rapidly through the worm, the spirals of which are closer and closer in measure as the temperature of the water lowers. Thence it enters the double jacket through P and N, makes a complete circuit of the cylinder, and runs out through the two-way cock, E. This water is returned either to the boiler or to some other point. As soon as the beer treated has reached a temperature varying between 55° and 65° (shown by the thermometer, F), the flow of the hot water is stopped, and time is given to the beer to take on a very uniform heat. Afterward, through D, a current of cold water is made to circulate, and this brings the beer to a temperature near that which the water possesses.

At this moment the cold water cock is closed, the apparatus is rocked upon its trunnions, and the water in the worm and double jacket is allowed to flow through the cock, H. After this the apparatus is replaced in a horizontal position, and it is then that it is necessary to cool the beer with rapidity. Nothing is easier when the storage cellars are supplied with a circular apparatus in which circulates an uncongealable liquid furnished by an ice machine. It is only necessary to borrow from this the liquid designed to bring the pasteurized beer to the required temperature. On making its exit from the apparatus, this liquid is sent to the refrigerating vat of the ice machine. Owing to the use of many-way cocks, these various operations are performed rapidly and simply. It remains for us briefly to indicate the processes employed for the introduction of the beer into the pasteurizer and for its removal therefrom.

The beer is forced directly from the storage tuns into the refrigerator, the filter, and the Kuhn apparatus by means of compressed air or carbonic acid under pressure. It enters the Kuhn apparatus through the cock, A, and, during the filling, it is necessary to take care to prevent the formation of froth by keeping up a constant counter-pressure in the apparatus through the cock, B. The introduction of the beer is arrested before the apparatus is entirely full, and the space left must be sufficient to allow of the expansion of the beer during the heating.

When the cooling is complete, that is to say, when the beer has returned to the temperature of the storage tuns, it is at once put into casks. To this effect, the cock, A, is opened, and then the cock, K, which is provided with a tube for the exit of the air. After this, air or carbonic acid under a pressure of 1 or 1½ atmospheres is admitted through the cock, B. Previous to this, it is necessary to take care to sterilize the pipes, casks, and bungs by means of an antiseptic wash, especially with a solution of bisulphite of lime. After they have been filled, the casks are at once closed.

If need be, there may be interposed between the apparatus and the casks an ordinary isobarometric apparatus, but the cooling of the beer to 2° or 3° renders it useless.

The duration of each operation varies, according to the quantity treated, from 1¾ hours to 2¼ hours.

It is merely necessary to examine our engravings to see that the Kuhn apparatus may be cleaned and kept in order with the greatest ease. After being dismounted, a jet of steam may be injected through the cock, A, for the destruction of such ferments as have not been sterilized at the temperature of 60°. At first sight, the use of an uncongealable liquid would appear onerous, through the consumption of artificial cold; but, upon a closer examination of things, it will be seen that a notable saving is effected in the material and the construction of the cellars in which large quantities of beer are usually stored, and the long continuance of which in casks is indispensable. Moreover, all large breweries now employ artificial cold, either derived from ice or, preferably, from a special refrigerating machine designed to maintain, in the storage cellars or the fermenting tuns, a low and constant temperature.

Now, in the usual conditions of manufacture for beers of good quality, with a mean duration of cellar storage, 22 gallons of manufactured beer absorbs about 30,000 negative heat units in low fermentation and 20,000 in high. On the other hand, the use of the Kuhn apparatus permits of giving beer a permanent and not a temporary limpidity, in absorbing, every ac-

count made for the two modes of fermentation, 17,000 and 12,000 negative heat units. There is, therefore, on this score, a notable benefit, which, in connection with the diminution of the expenses of the first establishment and of storage, clearly establishes the economical advantages of this process, the efficacy of which in the preservation of beer is fully recognized.—*Revue Industrielle.*

THE ISLE OF WIGHT.

ABOUT this island off the southern coast of England is the watering place called Ventnor, and one who has come through the tunnel which penetrates the Boniface Down and climbed down to the sea will never forget the impression made by the landscape, which is here very beautiful. But if we follow the coast to the west side of the island, we come to more grand and majestic scenery. Here the Needles rise from the sea, great towering masses of stone. Formerly there were five of these pyramids, but now only three remain. On the outer one there is a lighthouse to warn mariners of the dangers they are approaching. For the accompanying cuts representing these wonders of the coast

VIEW FROM THE NEEDLES CAPE

THE NEEDLES, ISLE OF WIGHT.

there is an atmosphere of calm and quiet in which one can rest from the bustle of the world, and this was what the Queen of Great Britain sought when she bought, in 1840, Osborne Castle from Lady Isabella Blachford, and with the help of the Prince Consort made a model English estate of it. The old house was torn down, and in its place a fine palace of the Italian style was built. Osborne Castle is situated between the towns of Ryde and Cowes. The queen of the island of the Isle of Wight we are indebted to the *Illustrirte Zeitung.*

AT a meeting of the Genevan Society of Physics and Natural History, M. Mallet exhibited two balls of almost perfect sphericity, about four inches in diameter, one black, and of vegetable origin, the other white, and of mineral origin, but both produced by a mechanical movement. The black ball had been found with another in a piece of oak which had long served as the shaft of a mill wheel. A cavity having formed in the wood, through disease or the work of some insect, the dust of the wood, with acquired moisture, had been rolled into this spherical form, growing in size, like a snowball (a slow process of many years probably, as the wheel was very old). The white ball, a calcareous pebble, was found with many others in a grotto traversed by a torrent which flowed into the Rhone.

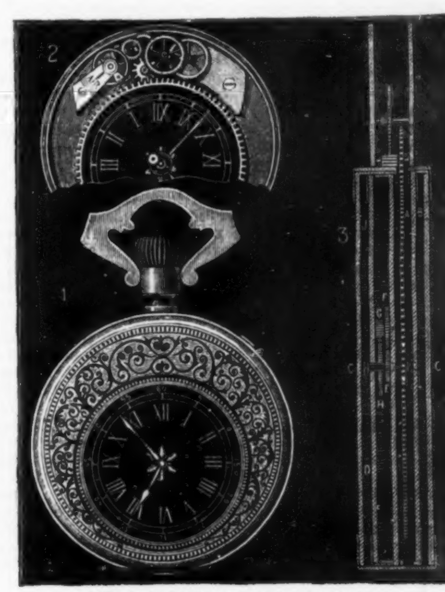
THE MYSTERIOUS WATCH.

THE Messrs. Schwob have just brought out quite a singular watch, the first specimen of which has been examined by us, and which will certainly puzzle more than one curious person. Every one now knows those mysterious clocks that still astonish the masses. A transparent glass dial suspended with two wires and provided with hands, and there we have a clock that tells the time. No mechanism, no transmission, nothing, and yet the clock moves to the minute. The secret of such mysterious affairs merits being revealed.

Several systems have been devised. Robert Houdin's was as follows: He selected a large glass dial, which he suspended with a wire, and in the center of which he fixed a minute and an hour hand. The former of these terminated in a piece in which a concealed clockwork movement displaced a weight. This latter, in revolving, kept constantly changing the equilibrium of the hand, which was thus obliged to move forward from minute to minute and effect the revolution of the dial in sixty minutes. This hand, in its revolution, communicated motion to the hour hand through a double gearing adjusted in the axis. There was nothing visible except the hands, and the whole thing operated regularly provided the dial was exactly vertical.

In another arrangement, there was concealed in the center, between the hands, a very small clockwork movement. As the hands were nicely balanced, it required but small force to move them; and here again people asked how it was that their motion could be effected.

Often, too, a glass dial has been placed at a certain height upon a glass column fixed to a base. In this case, recourse is had to a very strong clockwork movement. The transmission from the base to the hands is



THE MYSTERIOUS WATCH.

Fig. 1.—Perspective view of the watch. Fig. 2.—Details of the mechanism. Fig. 3.—Longitudinal section on a larger scale. C C, the front and back glass of the case. J, the dial. D, space in which move the hour and minute hands. E H G, the three wheels forming the dial train. A, glass disk with toothed metallic rim communicating with the movement. F B, two glass disks serving as a support to A.

effected through the intermedium of a glass tube, which, arranged in the center of the column, is not seen. The tube, carried along by the works concealed in the base, revolves and causes the hands to move forward.

Again, there have been constructed square glass clocks upon a base, with alternating transmission. One glass, concealed behind another, and directly actuated from the bottom upward by mechanism concealed in the base, rises and descends in an imperceptible manner, and these invisible oscillations suffice to drive the hands forward. It is useless to add that these various systems are costly and very liable to get out of order; so mysterious clocks have scarcely found their way into use among the people in general.

The Messrs. Schwob's watch belongs likewise to the category of mysterious devices; but it is solid, does not require to be hung perpendicularly, and operates with regularity in all positions.

It is, so to speak, a mysterious pocket "clock." A glass dial is set into a bezel in a silver rim, and two hands move, as if by magic, over the transparent glass without the least apparent transmission of motion (Fig. 1). The view through the glass is unobstructed, and a person can read his newspaper through the dial. What is the key to the enigma?

Let us open the watch. Behind the dial, C (Fig. 3), we find a glass disk, J D, which is not noticed when the watch is closed, and behind this there is a glass. The axis of the hands traverses the median disk, to which it is fixed, and rests on one side on the center of the dial, and, on the other, on the center of the glass. It is not difficult to see that the hands revolve, because the median disk itself revolves. But whence does it derive its motion? At the upper part of the watch, near the stem, the case forms a crescent (Fig. 2), and in this, notwithstanding the reduced space, it has been possible to find room for an entire ordinary watch movement. Now, the movable median disk is provided, at its circumference, with a toothed metallic ring. The teeth of this engage with those of a pinion

of the movement concealed in the crescent. Of course, we do not see the toothed circumference of the disk concealed behind the prolonged horns of the crescent; and we do not even suspect the existence of the central glass disk, the motions of which take place unperceived. So that a person who is ignorant of the artifice that we have just pointed out does not understand how the hands can move over the dial. The minute hand causes the direct revolution of the hour hand by means of microscopic gearings concealed under the interior support of the hands. This entire combination is well conceived, and, in ingenuity, surpasses the old mysterious clocks. The escapement is of the remontoir kind, and the watch runs thirty-two hours without stopping. In its simplicity, this new watch might well become the starting point of an interesting application.

How great the cost is of the large luminous clocks that are seen upon some of the public buildings is well known. It would be often possible to solve the problem much more economically. The Schwob watch is transparent, and might be placed in the path of a luminous fascicle, and it would then be easy to project the dial and hands upon a white screen, after the fashion of magic lantern images. In this way there would be obtained at will a phantasmagoric clock of colossal dimensions. The process might be profitably employed in certain edifices, wherever there was need of indicating the time at a distance, at night, to a large number of persons. And so, an invention that is simply curious may be called upon unexpectedly to render unforeseen services.—*La Nature.*

[Nature.]

TWO AMERICAN INSTITUTIONS.

I.—THE SMITHSONIAN INSTITUTION.

In 1826, Mr. James Smithson, F.R.S., an English gentleman (a natural son of the first Duke of Northumberland), in a fit of pique at the action of the committee of the Royal Society, who had declined to accept a scientific paper he had submitted, bequeathed to the United States of America a large sum of money, (£105,000), "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men."

The question of how knowledge might be best increased and diffused with £105,000 then arose for discussion.

The President of the United States applied to a number of persons, "versed in science and familiar with the subject of public education, for their views as to the mode of disposing of the fund best calculated to meet the intentions of Smithson and be most beneficial to mankind."

The president of Brown University (Prof. Wayland) proposed a university to teach languages, law, and mental philosophy (arts) without science. Dr. Thomas Cooper, of South Carolina, proposed a university to teach science only, and to exclude Latin and Greek, literature, law, and medicine. Mr. Richard Rush proposed a museum with grounds attached sufficient to reproduce seeds and plants for distribution; a press to print lectures, etc., and courses of lectures on physical and moral science, and on government and public law. The Hon. John Quincy Adams proposed the establishment of an astronomical observatory, with instruments, and a small library. Prof. W. B. Johnson proposed the establishment of an institution for experimental research in physical science. Mr. Charles L. Fleischman proposed the establishment of an agricultural school and farm. The Hon. Asher Robbins proposed a literary and scientific institution, and memorials were presented to Congress in favor of appropriating the fund for annual prizes for the best original essays on the various subjects of the physical sciences; for the establishment of a system of simultaneous meteorological observations throughout the Union; for a national museum; and for a library.

For ten years the Congress of the United States wrestled with the interpretation of the words "the increase and diffusion of knowledge among men." The discussions were numerous and irritating, and it was repeatedly proposed to send the money back to England. Finally Congress was wise enough to acknowledge its own ignorance, and authorized a body of men to find some one who knew how to settle the question. Joseph Henry was chosen. His idea was accepted and acted upon. "To *increase knowledge*, men were to be stimulated to original research by the offer of rewards for original memoirs on all subjects of investigation; to *diffuse knowledge*, the results of such research were to be published;" and in addition it was decided to issue a series of reports giving an account of new discoveries in science, and of the changes made from year to year in all branches of knowledge not strictly professional, as well as to publish occasionally separate treatises of general interest, and all these were to be distributed among the public institutions of the world.

In the result the Smithsonian Institution was established for the promotion of original research, and the diffusion of the same, and it now distributes to 3,700 public institutions in Europe, Asia, Africa, and America, the following publications:

"The Smithsonian Contributions to Knowledge," of which twenty-six volumes in a quarto series have been issued, comprising memoirs and records of original investigations, researches in what are believed to be new truths, efforts to increase human knowledge. "The Smithsonian Miscellaneous Collections," an octavo series, ready numbering thirty-four volumes, containing reports on the present state of our knowledge of particular branches of science; instructions for digesting and collecting facts and materials for research; lists and synopses of species of the organic and inorganic world, reports of explorations, aids to bibliographical investigations, etc. "The annual reports of the board of regents of the Smithsonian Institution" (thirty-two volumes), containing also very valuable records, catalogues, and memoirs.

Another part of the income was applied in accordance with the requirements of the act of Congress to the gradual formation of a library and a museum. But in 1866 the library was amalgamated with the library of Congress and lodged in the capitol. The library, however, is open throughout the year with equal facilities for students, including the free use of the books of both collections. In 1852, Mr. Henry established what is known as the "Smithsonian system of exchanges," whereby, in exchange for those of America, the scientific publications of societies and individuals throughout the civilized world are made accessible without cost to the students of science in America. This system has added to the library almost complete series of the transactions of many of the older societies of England, France, and Germany, which it would now be difficult, if not impossible, to replace. They comprise hundreds of works which, like those of the societies in question, can be obtained in no other way than by exchange. The collection is now the best in existence.

In his evidence before the Royal Commission on Scientific Instruction (English), June, 1870, Mr. Henry said:

"This is considered a very important part of the plan of operations. Not only are books distributed, but the Institution has commenced the practice of distributing specimens of natural history over the world and getting others in exchange. As an interesting fact in connection with this system, I may mention that all the lines of steamers convey the Smithsonian packages free of cost, and also that they are admitted through all custom houses without being opened, and free from all duties in all countries."

This generous system is still in operation, and has been very much extended.

In 1858 the United States government transferred the national museum (established 1842) to the custody of the Smithsonian Institution with the same amount of annual appropriation ($4,000) which had been granted to the United States patent office when in charge of it; but this annual appropriation has now been increased to about $40,000. A new museum was built at a cost of $350,000, and at the last session of Congress a bill appropriating $500,000, for the construction of a second museum building passed the Senate, but was not brought to vote in the House of Representatives. The secretary has no doubt, however, but that in a year or two a building much larger than the present one will be supplied.

The national museum is in three divisions—the museum of record, the museum of research, and the educational museum—and there are departments, with twenty-four curators and sub-curators, of arts and industries, ethnology, antiquities, mammals, birds, fishes, comparative anatomy, mollusks, insects, marine invertebrates, invertebrate fossils, plants, minerals, lithology and physical geology, metallurgy, and economic geology. There are, in addition, chemical and natural history laboratories, and a bureau of ethnology.

"So rapidly were the treasures of the museum increased by the gathered fruits of various government explorations and surveys, as well as by the voluntary contributions of the numerous and widespread tributaries of the Institution, that the policy was early adopted of freely distributing duplicate specimens to other institutions where they would be most appreciated and most usefully applied. And in this way the Smithsonian became a valuable center of diffusion of the means of investigation. The clear foresight which announced that the museum must soon outgrow the entire capacity of the Smithsonian resources was amply vindicated; but the strong desire of Joseph Henry to see established in Washington a *national* museum he did not live to see gratified" ("Memorial of Joseph Henry," discourse of W. B. Taylor, p. 285). He died May 13, 1878.

An extensive system of meteorological observations was instituted in 1849. About six hundred observers, scattered over the United States and the Territories, became voluntary correspondents of the Institution. This department was transferred in 1872 to the newly established meteorological department established by the government under the signal office of the War Department. The digested observations have been published in the "Contributions to Knowledge."

The memoirs in the quarto volumes of the "Contributions to Knowledge" (over 120) are universally recognized as valuable original authorities on their respective topics. There is no restriction as to the subject of research, and they consist of archæological, anthropological, botanical, geological, paleontological, meteorological, magnetical, physical, physiological, and philological observations, investigations on the solar system, the laws of atmospheric circulation, and systems of consanguinity and affinity. They have undoubtedly tended "to increase and diffuse knowledge."

The thirty odd volumes of the "Smithsonian Miscellaneous Collections" are of a more technical character than the "Contributions," including systematic and statistical compilations, scientific summaries, and valuable accessions of tabular "constants." Scientific men generally have applauded the value and acknowledged their indebtedness to publications comprised in this series, which include such scientific classics as Clark's "Constants of Nature," Guyot's "Meteorological and Physical Tables," Watson's "North American Botany," Binney and Tryon's "Land and Fresh Water Shells of North America," North American "Coleoptera" by Le Conte, "Diptera" by Loew, "Lepidoptera," by Morris, and "Neuroptera" by Hagen.

All these are distributed over every portion of the civilized and colonized world, and constitute a monument to the memory of James Smithson such as never before was built on the foundation of one hundred thousand pounds.

II.—THE JOHNS HOPKINS UNIVERSITY, BALTIMORE.

Johns Hopkins, a merchant of Baltimore, who died in 1873, in the seventy-ninth year of his age, bequeathed a large part of his fortune to two institutions which perpetuate his name—the Johns Hopkins University and the Johns Hopkins Hospital. Each foundation received an endowment of not far from three and a half million dollars, or about £700,000. The two institutions are separate corporations, but are closely affiliated. The university has just concluded its thirteenth year of work. Since its opening, in 1876, it has issued frequent statements of the development of its plans in the form of annual reports.

The Johns Hopkins University is an unsectarian foundation. There is no test for the assent of students or professors. This is the especial privilege of the new institutions for higher education that have sprung up of late years. "No hungry tradition treads them down." They approach the problem of education untrammeled by customary practice, yet, utilizing the experience gained by the older universities, they make more independent and original attempts at its solution.

Universities as a rule have grown from an aggregation of colleges; the university, in process of time, being evolved as a supplement to collegiate training. The Johns Hopkins University is an exception to this rule. In accordance with the terms of the gifts, the institution started with the idea of the university, in the higher conception of that word, as a universal school and a fostering mother. Not merely a place in which degrees are granted in the faculties of arts, sciences, divinity, law, or medicine, but as an organized force for the education of the community of the district in which it is placed, for deepening, purifying, and strengthening all good influences on the men, and the alliance of the men with the institutions. Institutions remain, but the men pass away—

The individual withers, and the world is more and more.

According to the thirteenth annual report of the university (September, 1887, to September, 1888), it appears that the academic staff included 57 professors, associate professors, and lecturers. There were 420 students; 199 were residents of Maryland, 196 came from other States of the Union, and 25 from foreign countries; 231 had already graduated, 127 had matriculated for the degree of B.A., and 62 were admitted as special students to pursue courses of study for which they seemed fitted, without reference to graduation. The university does not provide lodging or board.

There are seven distinct and parallel courses of college instruction adapted for matriculation, and the various elective groups for the degree examinations in the university. The subjects of the professors and lecturers last session were: history, political economy, mathematics, astronomy, physics, chemistry, mineralogy, geology, biology, psychology, pedagogics, pathology, Greek, Latin, Sanskrit, Indo-European philology, Shemitic languages, Romance languages, Teutonic languages, Anglo-Saxon, and English. The large and well appointed physical, chemical, and biological laboratories of the university have already been detailed in *Nature* (vol. xxxiii., p. 237).

Two degrees only are granted—the bachelor of arts and the doctor of philosophy; and since degrees were first conferred in 1878, 177 have attained the baccalaureate degree, and 131 have been advanced to the degree of doctor of philosophy.

There are twenty fellowships of $500 each. The examination for these is, in a certain sense, competitive, but not with uniform tests nor by formal questions submitted to the candidates. The applicants' previous record, and the professors' record, is taken into consideration.

"Those who are appointed are expected to proceed to the degree of doctor of philosophy. The appointments are not made as rewards for good work already done, but as aids and incentives to good work in the future; in other words, the fellowships are not so much honor and prizes bestowed for past achievements, as helps to further progress and stepping stones to honorable intellectual careers. They are not offered to those who are definitely looking forward to the practice of any one of the three learned professions (though such persons are not formally excluded from the competition), but are bestowed almost exclusively on young men desirous of becoming teachers of science or literature, or proposing to devote their lives to special branches of learning which lie outside of the ordinary studies of the lawyer, the physician, or the minister. Appointments are rarely, if ever, made of graduates of more than five years' standing."

There are also twenty graduate scholarships of $200 each for those who have taken the baccalaureate degree. There are also thirty-eight ordinary and honorary Hopkins scholarships ($250 annually and free tuition) for promising young men.

Courses of public lectures, designed primarily for the members of the university, and supplementary to the regular class room work, are given each session. The admission of the public is by ticket, to be previously obtained free. The courses for 1887–88 included: Ten lectures on some of the problems of great cities; six lectures on the local study of natural history; nine lectures on the history of the science of electricity and magnetism; eleven lectures on the causes which led to the French revolution; four lectures on Greek lyric poetry; eight lectures on the topography of Athens.

The university library consists of 35,000 volumes. And it is lately reported that the valuable scientific collection of the Maryland Academy of Sciences has been presented to the university.

But the great point of this institution is its efforts in the direction of the endowment of scientific research. Prof. Newcomb, one of the professors of the university, said in 1876 of America what is very true of Great Britain: "We are deficient in the number of men actively devoted to scientific research of the higher types; in public recognition of the labors of those who are so engaged; in the machinery for making the public acquainted with their labors and their wants; and in the preliminary means for publishing their researches." The Johns Hopkins University has encouraged scientific research, and the publication of its results, to a large extent; not only by training young men in the methods of exact science, and fitting them for the scientific service of the government, for scientific and technical laboratories, and for the teaching profession, but also by the publication of journals and monographs detailing the results of scientific study. The trustees, determining to encourage the heads of departments and other qualified scholars to contribute each in his own way to the advancement of the science which he professed, started five periodicals, conducted by professors and graduates, and aided by the university chest, namely: *The American Journal of Mathematics*, 10 vols., edited by Prof. Newcomb; *The American Chemical Journal*, 10 vols., edited by Prof. Remsen; *The American Journal of Philology*, 9 vols., edited by Prof. Gildersleeve; "Studies from the Biological Laboratory," 4 vols., edited by Prof. Martin and Dr. Brooks; and the "Johns Hopkins University Studies in Historical and Political Science," edited by Prof. H. B. Adams, the seventh series of which is in progress. All of these publications are considered on both sides of the Atlantic to be of the greatest value. *The American Journal of Psychology*, "Modern Language Notes," and "Contributions to the Study of Archæology," are also edited by members of the academic staff, and there are university societies on all these subjects.

The university also publishes *University Circulars* monthly, containing scientific notes in biology, chemistry, history, political science, mathematics, physics, philology, philosophy, logic, etc., besides the usual annual reports and special publications, such as the "Reports of the Chesapeake Zoological Laboratory." This is a laboratory of about fifty individuals at ten stations, and the results of their work at the seashore, in the study of natural laws in their simplest manifestations, from 1879 to 1886, include ninety-nine titles.

Dr. Gilman, the president of the university, reported at the tenth anniversary that 176 former students were known to be engaged in the work of teaching, mostly in colleges, and that among the former pupils are eighty physicians, thirty-eight ministers, and thirty-four lawyers. There were no exact statistics of those engaged in scientific pursuits.

Such are the beginnings of the Johns Hopkins University. Those engaged in the work of higher education in this country will fully appreciate the fortunate circumstances in the inception of the institution, a benefaction of £700,000 for endowment, carefully selected trustees, to whose wisdom, moderation, and farsightedness much is due; a wisely organized constitution, able professors and teachers, gauged by the standard of work done and success achieved, and foundations to assist all these contributed by a critical and discerning public. The institution started full of promise, and it is redeeming its promise with a rapidity unparalleled in the history of academic institutions.

J. TAYLOR KAY.

SPONTANEOUS HUMAN COMBUSTION.

(*Catacausis ebriosus.**)

By Dr. G. ARCHIE STOCKWELL, F.Z.S. (Member of New Sydenham Society, London), Detroit, Mich.

SPONTANEOUS ignition, in any condition of the human body with which we are familiar, whether in life or death, health or disease, by many physiologists (perhaps a majority) is regarded as exceedingly problematical, not to say mystical. Further, animal tissues generally are scarcely at all consumable by fire, and are reduced to ashes only under the influence of most intense and prolonged heat. Even the corpses of confirmed inebriates are no exception; and morbid material saturated by long immersion in spirits burns only until the alcohol is consumed, and with no change other than slight charring of the exterior.

That individuals may render their bodies inflammable by the vice of habitual dram-drinking, from a chemical standpoint, is within the range of possibility; but in most instances recorded of ignition and incineration of the human economy, the presumption is not in favor of true spontaneity, but of an external cause, or of direct contact with fire. Indeed, there can be no doubt but that individuals have, in some strange and inexplicable manner, caught fire and been partially or almost wholly consumed; and while some of these accidents are directly or indirectly traceable to grates, stoves, lamps, candles, and pipes, or to electricity and lightning strokes, a few have defied all attempts to elucidate a cause, and it is these last, apparently, that gave rise to the theory of spontaneity.

M. Duvergie, from personal observation and study, unhesitatingly upholds the possibility and probability of spontaneity, supposing it may arise from secondory modification of the forces of the body, as the result of the primary absorption of alcohol, that are thus transformed into inflammable compounds.† So, too, MM. Bianchini, Maffei, Le Cat, De Azye, Kopp,‡ and distinguished contemporaries, upheld the idea that ignition of the body does not always depend upon the approach of a burning object, but that it may be developed by or through chemical changes occurring through incipient decomposition occurring within the economy itself; and M. Pierre Lair remarks: "While the accounts of this most horrible malady are apparently worthy of but very little credence, they must unhesitatingly be believed, coming as they do from individuals whose veracity is unimpeachable, and who are distinguished for their learning; further, it is no more surprising to meet such incineration than to encounter a discharge of saccharine fluid (*diabetes*) or bones softened to a state of jelly (*mollites ossium*)."§

As the result of extended and careful chemical experimentation, M. Marc concluded that animal tissues, exclusive of alcoholic saturation, might engender gases, *per se*, that will ignite on the approach of fire, flame, or electrical current, and cites as corroborative an incident occurring in the *post mortem* room of Hotel Dieu: A corpse had been held in the dead house for eight days, awaiting autopsy, and when examined was in an advanced stage of decomposition. It was swollen and bloated from distension of cellular tissue with gas and bloody serum, the former presumably carbureted hydrogen, as it caught fire and burned with a bluish flame on the approach of a candle; the same gas also filled the cavities of the thorax, brain, and abdomen.‖ Also, Morton saw flames issue from the body of a pig; Bonami and Ruysh with a lighted candle set fire to the vapor issuing from the abdomen of a woman they were opening; and a butcher on opening the body of an ox that had died after a malady which had swollen him considerably, was severely burned by an explosion with flame which rose to the height of four or five feet.¶

There are several well authenticated cases recorded in medical literature, where flames were communicated to the fingers, or other points of the bodies, of apparently healthy individuals, setting fire to clothing, and even the cloths employed to dress the burns. Two sad cases were those of a youth and a girl, neither out of their teens, and in no sense either intemperate or obese. While water would extinguish the flames that enveloped the hands, the fire broke out again spontaneously.**

* From *katakausis*, "burning," adopted by Dr. Thos. Young (*Medical Literature*, 1813). Dr. Good (*Study of Practice of Medicine*, 1829) subsequently added the specific title *ebriosus*, defining such *catacausis* as: "A constitution inflammable in consequence of long and immoderate indulgence in spirituous liquors; the combustion easily excited or spontaneous."

† *Philosophical Transactions*, vols. xiii., xiv.

‡ *Surgical Review;* Ploquet. *Litterat. Med.;* Dupont, *De Corporis Humani Incendiis Spontaneis.*

§ *Journal de Physique*, ant. viii.

‖ *Gazette Medicales*, 1840.

¶ *Memoires Academie des Sciences*, Paris.

** *Philosophical Transactions*, vol. xiv.

A still more remarkable case in some of its features is that related by the Italian surgeon, Joseph Battaglia.

"Don G. Maria Bertholi, a priest of Mount Valerius, went to the fair of Filetto, and afterward visited a relation in Fenilo, where he intended to pass the night. Before retiring to rest he was left reading his breviary; when, shortly afterward, the family were alarmed by his loud cries and a strange noise in his chamber. On opening the door he was lying prostrate on the floor, and surrounded by flickering flames and in a most deplorable state. The integuments of the arms and the back were either consumed or detached in hanging flaps. The sufferer was sufficiently sensible to give an account of himself. He said that he felt all of a sudden as if his arm had received a blow from a club, and at the same time he saw scintillations of fire rising from his shirt sleeves, which were consumed without having burned the wrists; a handkerchief which he had tied round his shoulders, between the shirt and the skin, was intact. His drawers were also sound; but, strange to say, his silk skull cap was burned, while his hair bore no marks of combustion. The unfortunate man only survived the event four days, when mortification of the burnt parts was most extensive, and the body emitted intolerable putrid effluvia. The circumstances which attended this case would seem to warrant the conclusion that the electric fluid was the chief agent in combustion." *

Occasionally, also, are encountered topers whose pulmonary exhalations, on meeting with flame, give off scintillations of blue light. Such an individual perambulated the streets of Brooklyn and New York in 1877, exhibiting this phenomenon in bar rooms and low restaurants, for a few pennies, respiring through a wire gauze strainer into the flame of a taper or gas jet. This was also his method of securing the desired libations of the ardent, and it may be his death by drowning only anticipated a more horrible demise.

Again, an inebriate patient died in the Liverpool Alms House in 1844,† who for twenty minutes prior to dissolution emmitted a luminous breath likened by the attendants to "a red-hot coal-like streak;" and a parallel case, in the same year, occurred in the practice of Dr. Huggins, ‡ of the island of Trinidad, W. I.

The development of the electrical spark in connection with tissues saturated with spirituous liquids, especially if (as is usually the case) there is an abundant deposit of adipose in the cellular substance, is regarded by many as sufficient to induce spontaneous cremation in the human subject. It is well known that spirits may be so quickly absorbed into the circulation as to be speedily diffused to the most remote portions of the economy, and to appear in the pulmonary and renal excretions. MM. Cuvier and Dumeril were struck with the strong alcoholic odor obtaining in the corpse of a man who met his death by swallowing an enormous quantity of brandy, in compliance with the terms of a wager.§

M. Breschet mentions like phenomena observed in the corpses of criminals that had been freely supplied with liquor prior to undergoing decapitation; and he adds that, "partially *decomposed* human adipose, saturated with alcohol, frequently ignites, burning with fierce flame."‖

In any event human catacausis must arise from chemical changes occurring within the economy itself. Combustion has even been asserted to arise spontaneously in inorganic materials for the same reason—substances that under all ordinary conditions are non-inflammable, such as heaps of ashes that had remained undisturbed for a period of years.¶ Various chemical substances also, themselves individually inert, on combination may occasion spontaneous or latent heat, leading to explosion, combustion, and flame, nitro-sulphuric acid with an essential oil for instance. May not then like changes occur within an organic body under certain conditions? And if carbureted hydrogen can be developed, as in the case related by M. Marc, *et sequiter*, as already related, there is every reason to believe the more inflammable phosphureted gas which bursts into flame on contact with the oxygen of the atmosphere may be evolved. Certainly the constituents necessary are not lacking in the one case more than in the other, and decomposition may even be far advanced long before the vital spark forsakes the body. Sturm, Bartholini, and Gaubius ** record fiery eructations in which, no doubt, phosphureted hydrogen was formed in the stomach and ignited by contact with air; the *ignis fatuus*, "will o' the wisp," "elf candles," etc., are supposed to owe their origin to the same gas, and are found only in neighborhoods in which decomposition of animal and vegetable matters are constantly taking place, as manure and refuse heaps, slaughter house yards, and low marshy grounds, and in Oriental countries they are especially prevalent in and about those localities where bodies are inhumed at shallow depths and the ground wont to be cracked and fissured by the torrid heat of the sun. ††

Medical and medico-legal literature record some seventy-six cases of catacausis occurring within a period of two centuries, and in spite of the various attempts at explanation, there are many circumstances connected therewith that, in the light of present knowledge, to say the least, are mysterious.

First.—The victims are stricken down suddenly; the combustion is phenomenal in that it is for the most part confined to the principal repositories of the fluids of the body—abdomen, chest, and head. On the contrary, the victims of ordinary accidents by fire rush hither and thither in their frenzy, succumb only when overpowered and exhausted, and the extremities suffer from the flame.

Second.—In accidents, the clothing is destroyed, whereas in catacausis it suffers little except as brought in immediate contact with the fire; the flame of the latter appears inert so far as ordinary combustibles are concerned, which is evidence of its hydrogen derivation.

Third.—The residue resultant upon catacausis is of

* *Curiosities of Med. Experience.* Millengen, 1837.

† *Transactions of the Liverpool Pathological Society*, 1845.

‡ *Lancet*, Sept. 6, 1845.

§ *Robie on Alcohol.*

‖ *Gazette Medicales*, Dijon, 1844.

¶ *Amer. Jour. Sciences*, 1842; Appleton's *New Am. Cyclopedia*, art. "Combustion."

** *Curiosities of Medical Experience*, vol. i.

†† Forbes' *Oriental Memoirs.*

peculiar character, and unknown to any form of direct combustion, resembling rather the product of *distillation* of animal tissue, being a gray or dark soot-like substance with oleaginous admixture, analogous to lamp black and of overpoweringly fetid odor.

In some few instances the body has been detected in the very act of incineration, a blue flickering flame being emitted, perhaps, but oftener presenting a stifled form of combustion without flame, with dense, dark, offensive smoke, and all authors agree that water, far from arresting, tends to aid and foster.

A case reported by Mr. Devonald, in 1883,* exhibited an unusual amount of flame, and is supposed to have furnished the material for the tragic demise, respectively, of "Mistress Faithful" and "Old Krook" as depicted by Marryat † and Dickens.‡ In another instance ignition occurred seemingly as a sequel to an attempt to light a pipe with a live coal, the flame, as described by eye witnesses, "bursting out from the throat and bosom all at once, the woman falling instantly as if felled by a bludgeon." § Strange to say, also, the majority of victims are women advanced in life, obese, and addicted to the immoderate use of *gin*, a liquor that at its best is rich in empyreumatic oils. Possibly the key to this may lie in the facts ascertained by observation, that human catacausis seldom occurs in summer, but principally during severe cold and frosty weather—that there is a tendency to the accumulation of fat, more especially in females after a certain age, irrespective of the use of ardent spirits (and women by reason of peculiarities of nervous organization are apt to carry intemperance to greater extremes than males), and that empyreumatic oils, which are important constituents of all distilled liquors, during cold and damp weather tend to supply fuel for the evolution of animal heat, rather than exert their customary physiological action. Millengen asserts (though on what authority I am unable to determine) that experiments were undertaken in the United States about 1836,‖ in which blood flowing from the arm of a man deeply addicted to spirituous liquors, "actually took fire when placed in contact with a lighted taper."

Dr. Apjohn, of Dublin, with exceeding minuteness of details, cites three cases of catacausis occurring in Ireland prior to 1830, one of which at least affords presumptive evidence of being spontaneous.¶

A woman, sixty years of age, residing with her brother in county Down, retired one evening with her daughter, both, as was their constant habit, being deeply intoxicated. A little before daybreak, the other members of the family were awakened by a dense and offensive smoke that pervaded the entire dwelling. This was traced to the apartment of the old woman and daughter, and found to proceed from the body of the former, which, to employ the language of the brother, "appeared to be burning up with an internal fire," the smoke issued "from every part of the chest, which was as black as a coal, but with no appearance of flame."

The combustion was with difficulty smothered, when life was found to be extinct. While the remains were being removed into a coffin, which was done as soon as possible, they were constantly dropping in pieces.

The daughter, not less intoxicated than the mother on retiring, sustained no injury, and was with difficulty aroused. Also the couch, curtains, and bed clothing exhibited no evidences of the accident other than stains due to smoke and grease. According to the sworn testimony at the inquest, there was neither fire nor light in the house, neither was there means of procuring available to the victim or her daughter, owing to precautions on the part of the brother, who deemed them incompetent to be trusted therewith. Intemperate for years, the old woman has been grossly so for some weeks prior to her demise.

Another case of catacausis presenting peculiar features, but that cannot be regarded as spontaneous, occurred in the Commune de Surville, near Pont L. Eveque, France, in the morning of Sept. 8, 1835, involving the lives of two individuals, one an old man aged seventy-five, the other his wife, ten years younger, both of whom had long been addicted to the immoderate use of brandy.**

On the morning in question the Procureur du Roi was notified that a most sickening odor proceeded from the dwelling occupied by the couple who could not be roused, and moreover when last seen were in a beastly state of intoxication.

On forcing the door, a strong empyreumatic odor was observed; and in the principal room, the door, latch and casings, the windows and various articles of furniture, including glasses and bottle upon the table, were bedaubed with a grayish, sticky, unctuous, stinking soot. On the floor lay a shapeless carbonized mass, in which little besides four lower extremities could be recognized.

Two of these legs were dressed in black woolen hose and prunella boots, one of the former being slightly charred near the knee, though the subjacent tissues exhibited no unusual appearance, save that here and there portions of the epidermis protected by the boots were slightly reddened. Three inches above the knees both thighs had been converted into a black shapeless unctuous mass; and except for a small portion of hip bone, nothing could be recognized of the inferior portion of the trunk, which had parted from the superior at the small of the back junction of the sacral and lumbar vertebræ. Appearances indicated that this corpse had fallen at right angles across the other, the weight of head and shoulders securing separation after incineration. The two or three bones of the spinal column that were thus exposed were thoroughly calcined, and their whiteness contrasted singularly with the dark, shapeless, pitchy, carbonaceous mass that represented the thorax and contents. The ribs and breast bone were completely destroyed with the exception of the spinal ends of two of the former upon the left side that, though somewhat charred and blackened, still clung to their respective articulations. The neck had entirely disappeared, except for the calcined remnants of vertebræ; and the head was represented by a white, rounded, incinerated mass, that crumbled into powder with an attempt to lift from the floor.

* *British Medical Journal.*

† *Adventures of Jacob Faithful;* first published in 1838.

‡ *Bleak House;* first published in 1854.

§ *Cyclopedia of Practical Medicine*, 1848.

‖ *Curiosities of Medical Experience*, vol. i. London, 1837.

¶ *Cyclopedia of Practical Medicine.*

** *Jour. des Connois. Med. Chirurg;* Sept., 1836.

Of the other corpse, the right thigh bone, flexed upon the knee, the foot pressing the floor, was snapped across at its lower and middle third. The knee joint was laid open and completely desiccated; the ankle joint infiltrated with serum. Completely detached, the left leg exuded at its upper extremity a most hideously fetid oleaginous fluid; throughout its anterior surface it was bare, and spotted with vesicles distended with reddish serous fluid and gas, the latter being dissipated in blue flame when brought in contact with the atmosphere; posteriorly the whole extent was scorched or burned to the bone, which itself was more than half calcined. The pelvis and thorax, including their contents, were almost wholly consumed or converted into unctuous charcoal, the sole exception being the liver and right lung, which had been protected by the carbonized layers of clothing and superadded mass of the other corpse, the two in this locality being so fused and welded together, as it were, as to be almost inseparable. Spine and ribs were alike reduced to charcoal of quite solid consistence; and though the head retained its outlines, the features were unrecognizable owing to sooty and unctuous matters that filled the hollows of the eyes and covered the chin and cheeks, hiding mouth and nose. When this corpse was raised, the skull crumbled in numerous pieces, the posterior portion remaining on the floor, within which, resting upon the spinal opening, was the brain, "shriveled and hard as a piece of horn, not larger than a hen's egg."

Of the arms of both victims, nothing remained beyond a few incinerated fragments of the bones of the hands and a calcined portion of bone pertaining to one forearm. Exclusive of the lower extremities, the debris collectively did not equal four pounds weight.

Close to where the heads lay was the fireplace, the fender of which, along with a gridiron, lay beneath the bodies. The grate was filled with ashes, and between the heads lay a brand still ignited ("*un tison encore enflamme*"). Near the feet of the upper corpse (presumed to be the female) stood a table, not in the least injured, and a chair slightly scorched as to varnish; and on the former a bottle and two glasses, all containing *eau de vie*. Counting from the time the victims were last spoken to the entrance of the Procureur du Roi, the accident must have taken place within twelve hours, and judged from the consumption of brandy, less than half this time.

Within the past five or six years, several cases of catacausis have been placed on record, which, with the list previously accumulated, serve to establish beyond all cavil the fact that an abnormal combustibility of the human body may supervene as the result of morbid changes, which, however, does not necessarily imply spontaneity, or even ordinary ignitability. For instance, the case chronicled by Dr. J. Mackenzie Booth as occurring in Aberdeen, Scotland, February 19 last year,* was that of a pensioner aged sixty-five, of most intemperate habits, who retired to his room in a stable loft at 9 P. M. and was found at eight the next morning, as an incinerated corpse, all the soft part being consumed. The chance of the application of fire is here distinctly stated, though he was observed through a skylight to strike a light, which a few moments later disappeared. He was deeply intoxicated at the time he retired. In any event, the combustion was remarkable, as it was evident the unfortunate were stricken suddenly, and died without a struggle, the most incombustible parts of his body suffering chiefly.

Again, Middlekamp and G. O. Williams report two remarkable incinerations occurring recently in the United States, that properly belong to the classification of catacausis ebriosus, though induced by gunshot wounds. In one (Middlekamp's case) the victim, aged sixty-six years, was a drunkard of twenty-five years' standing, and the heat so intense as to melt the steel ramrod which was the missile fired and that transfixed the thorax;† the other, a youth of twenty or thereabout, also addicted to spirits, and intoxicated at the time of his demise.‡ In the former the body was consumed, excepting the lower portions of the inferior extremities; the latter was less burned, but still gave evidence of most phenomenal heat, which had little effect upon surrounding objects of ordinarily combustible nature. A third case, occurring in Seneca, Illinois, in 1885, reported by Dr. Clendenning,§ was an old Irish woman extremely addicted to drink. She was the last of her household to retire, and to extinguish the candles, the sole means of illumination; there was also a fire in the kitchen range eight feet from where the body was discovered, but no evidence of a struggle. The inner walls of the dwelling were covered with greasy, foul-smelling soot, and her husband, presumably also intoxicated, was found asphyxiated in his chamber. The skull and cervical vertebræ of the woman, as well as chest, were very nearly reduced to cinders, and the entire remains of a woman that in life weighed upward of one hundred and sixty pounds did not now amount to twelve pounds.

Since three-fourths of the body is water, and enormous heat required to reduce to ashes, as exhibited in the details pertaining to cremation, we may inquire what it is that imparts such abnormal combustibility. It has already been shown that animal tissues are not inflammable by mere saturation with alcohol. Hence we must fall back upon what a recent writer terms the "fanciful phosphureted hydrogen theory." But the hypothesis, far from being fanciful, appears practical when carefully studied, recognizing the fact that morbid changes, inducing partial, or more or less complete, decomposition may and do occur within the economy prior to death. It is further explained, too, by the now generally accepted microbe doctrine, of which Prof. Chas. Bouchard, of Paris, remarks:

"We now know that animals transform organized matter. They reduce a part to the mineral state—to water and carbonic acid. As for the rest, the work of destruction is unfinished. Here is demanded the co-operation of microbes. After death they alone can restore the body to its entirety in the mineral world by disorganizing its tissue, which they transform into various chemical products, viz., water, carbonic acid, hydrogen, carbureted hydrogen, sulphureted hydrogen, phosphureted hydrogen, etc. Often this disintegration begins before life is extinct." Thus an inflammable condition may arise, though necessarily it is incompatible with the supposition of health.

In spite of the general discredit cast upon spontaneous combustion and inebriate catacausis by medical writers, such conditions and accidents are recognized, and have been repeatedly affirmed, by legal authorities. Several cases of mysterious death have led to the trial of individuals for murder, in each of which, save one, the proof of catacausis was conclusive. The one exception was the death of the Countess of Gaerletz of Darmstadt in 1845-50, for which one John Stauff was tried for his life. The defense was wholly assumptive and theoretical, and after many delays, overridden by post morten examination, which revealed fracture of the skull; moreover, the body of the unfortunate woman was most consumed in those parts ordinarily immune to the combustion of catacausis.

Detroit, Michigan.

* *British Medical Journal*, April 21, 1888.

† *St. Louis Med. and Surg. Jour.*, October, 1885.

‡ *Med. Record*, August 13, 1887.

§ *Therapeutical Gazette*, June, 1889.

POISONING BY COTTON DYED WITH LEAD CHROMATE.

By T. H. WEYL.

DR. CARRY, of Lyon, reports on a series of poisoning cases among women engaged in winding yellow or orange yarns. All the symptoms indicated lead poisoning. Prof. Pouchet, of Lyon, however, found in three samples submitted to his examination no lead, and stated that the yarns were mordanted with a salt of antimony and dyed—No. 1 with Martius' yellow, No. 2 with Jaune solide, and No. 3 with "Jaune N. Poirrier." The writer obtained, at the request of Dr. Carry, specimens of the suspected yarns, and found, in concert with G. Schulz, of Berlin, that they were dyed with lead chromate, and not with the dyes above mentioned. Both the lead and the chrome were not merely qualitatively recognized, but quantitatively determined. How Prof. Pouchot can have been deceived is questionable. The use of lead chromate is legal both in France and Germany. In an appendix the author mentions that he found in a saddler's workshop in Berlin sewing thread dyed orange with lead chromate. It could scarcely be doubted that lead poisoning might ensue from the continued use of such thread.—*Zeit. f. Hygiene* and *Chemiker Zeitung*.

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